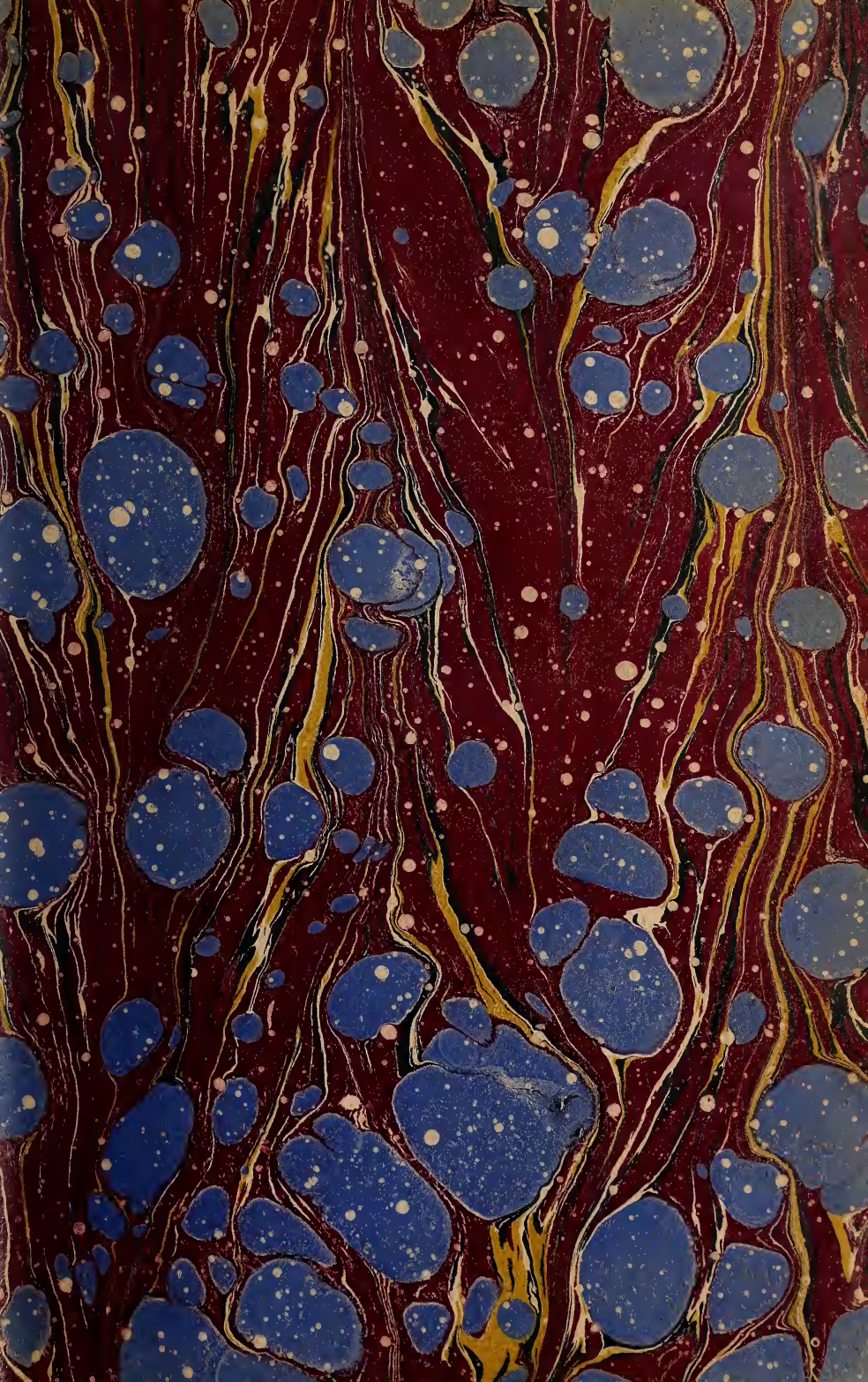

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PAPERS

READ BEFORE THE

ENGINEERING SOCIETY

OF THE

SCHOOL OF PRACTICAL SCIENCE

TORONTO

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PREFACE.

In the Spring of 1885, through the efforts of Messrs. Herbert Bowman and T. Kennard Thomson, assisted by Professor Galbraith, was laid the foundation of the Engineering Society of the School of Practical Science. With Professor Galbraith as first president, succeeded in turn by students, the Society has had a very satisfactory progress and growth, the evidence of which may be seen by comparing memberships of the present and inaugural years. Beginning with a few members it has increased to over 200. Meetings are held on the second and fourth Tuesdays of the academical year, at which papers and questions of engineering interest and importance are read and discussed. The programmes are varied at times with discussions of questions not relevant to the papers read, which offer opportunities to each member to benefit himself and the Society by giving the results of his experiences and individual research in matters of engineering interest.

While at the same time giving every possible attention to the interests of the undergraduates, those of the graduates are not lost sight of. To this end papers read during the previous session are published each year and distributed.

The papers in the present edition have been contributed chiefly by students, and have been carefully selected; those bearing the mark of originality and personal research being published. Though at first sight this seems like putting an embargo on the efforts of the student, who during the session has his time pretty fully occupied with the work of the course and can ill afford the time for the preparation of a paper otherwise than by compilation, it is thought that though the paper may be short it is worth more to the Society than a lengthy and compiled one, provided it be original and supply ample food for discussion. This latter characteristic fixes the standard of excellence on which is based the selection.

Special attention is called to the papers of Messrs. C. Marani and J. A. Duff, B.A., graduates, which when read elicited lively discussion.

The general committee hopes that graduates, now engaged in active work, will add their quota to the interest of the meetings by contributing papers closely bearing on their work, which to the student proves a great source of interest by providing a means of comparison between the practical and the theoretical.

The present edition consists of 1000 copies, which will have a wide circulation among engineers and surveyors. Exchanges are also made with other Associations, whereby the distribution is extended.

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

Gentlemen,—It is my first and sad duty to-day to refer to the loss, we as a Society have sustained, through the death of our late past president, Mr. J. K. Robinson. Those of you who knew him personally can well understand my inability to pass a eulogy worthy of so high and noble a character. He was endeared to us by many ties, fraternal and social. As leader of our executive he was energetic, zealous in promoting the best interests of our Society, upholding with honor and dignity the high position you had conferred upon him, which he so well merited and so ably filled. As a student, assiduous, as a friend uniformly kind, gentle and unassuming. His religion was decided, but never obtrusive nor made obnoxious to his fellow students. His acts were the outcome of principles founded on a true conception and a high ideal of right. He was a man in the highest sense, and as a man, he has left us the richest of all legacies, an example of true manhood, industry, and truth.

It is my privilege to thank you for the position I occupy to-day, the highest in your power as students to confer on one of your number, and although I cannot adequately express my feelings, this inability does not in any degree lessen my gratitude to you for this expression of your confidence.

I would confess to a feeling of self-deficiency to do full justice to the position, were it not for the fact that you have elected to assist me a committee, whose sound judgment in matters deliberative can be fully relied on. Beside this, I feel full confidence that each one of you

recognizes his individual responsibility in matters pertaining to the Society, and that you each have come with a full determination to do all in your power to make the session on which we are entering one of the most successful and progressive in the history of the Society. I cannot hope to reach the high plane of executive ability in which our Haultain, our Duff, and our now lamented Robinson moved, but I anticipate that that my lack in this respect will be more than compensated for by your own extra endeavors, and I will do my utmost to interpret your wishes as a Society, and to prevent the occurrence of anything that would cause you to regret your action in placing me in the position you have.

On behalf of the Society I welcome those of you who are here for the first time to-day, and who, although not as yet formally members, show by your presence here the desire to take part in student associations and Society work, and who, therefore, we consider virtually members, and co-workers in fulfilling the objects for which our Society was formed.

There is sometimes a tendency on the part of young students to deprecate, or at any rate to not fully appreciate the advantages and benefits to be derived from a regular attendance on the meetings of our Society. This is in every case the fault of the individual. If you come here expecting to be entertained by a comic concert, or musical recital, you will, I admit, be disappointed. But if you come to learn, to improve your mind, to increase your store of knowledge, you will be more than satisfied with the opportunities afforded you. Our meetings are always instructive, always entertaining to those who come to the School with their minds made up to excel in the profession they have chosen, and thus be worthy students of a grand institution. In the discussion of papers read before the Society, in the consideration of business in connection with the Society, you will be expected to take part. To point out errors, to suggest improvements, and to give your reasons for each in an intelligible and concise manner, will be your duty as well as your privilege, as a member of our Society. This is an important and useful accomplishment for any one, but it is particularly important and useful to engineers who have to deal with municipalities and corporations, the individuals of which, as a rule, are none too well supplied with mathematical perception.

But there are other and just as valuable advantages to be gained as those pointed out. I refer to the opportunities that a society of this kind offers for the study of human nature as exhibited in your fellow-students, and thereby a comparative and beneficial study of yourself. In our debates and discussions there will be differences of opinion, cross-firing of words, the faults and virtues of the one individual will be brought in contact with the opposite qualities of the other. In the collision there

will be a dissipation of the excess of each, or rather, perhaps a harmonious blending of opposites; each will come out of the fray a more fully developed, a more symmetrically formed character, better able to cope with the opposition that we will each receive when we leave college and enter upon the stern conflict of life.

Then there are the privileges in connection with the Engineering Society Library. There you find all the latest literature referring to engineering and architectural subjects and work, books of reference, models, plans of work; you have the opportunity of getting your drawing paper at cost price from the librarian, as well as having a cosy and comfortable place to put in a spare half-hour in storing your mind with useful knowledge.

I would like to impress upon you at the beginning the importance of weighing well every question that is brought before you as members of our Society for consideration. Every motion that is brought up for discussion is going to have in its acceptance or rejection, an effect either progressive or obstructive to our Society. How necessary it is then that you should each give it your calm and careful deliberation before either sanctioning or opposing it by your vote.

There is sometimes a tendency in this, as in other societies, to rush a motion through, before its full meaning has dawned upon the majority of the members; some vote mechanically, some vote through the influence of others who they think ought to know, some conscientiously refrain from voting at all. Let your actions through the coming session be such that none of these imputations can be brought against you. Be honest in your consideration of the questions, independent in your decision, and use your franchise accordingly. In this way you will be best fulfilling your duty to the Society.

It may not be out of place to say a few words here in connection with the advance our School is making, and the corresponding progress of our Society. The last year has been a red letter one in the history of the institution, whose progress has been marked by many great improvements during the past few years. To attempt to give an historical account of how the School of Science has risen to the proud eminence upon which it now stands would be out of place here, and to show how the Engineering Society has at the same time attained its present standing, is equally laborious. But certain it is, the Engineering Society has become an organization worthy of its connection with our School and of the ambitious aim to which it strives, and such an organization as every loyal son of his *alma mater* should be proud of.

Our Society has grown in influence during the past year, and if there

were no other proof of the fact than the increased attendance which was shown, such would be sufficient; but besides this we have a more important proof: that is, the increased interest which was manifested in the Society's affairs and proceedings. From the first speech of welcome last October, until the last echoes of the soul-stirring "Auld Lang Syne," which we sang here at twelve o'clock on the night of 28th March, had died away, the spirit of interest was unfailing, and as now we enter upon another bright and propitious cycle, we exhort again an increased manifestation in you of that spirit of loyalty and interest which has made this Society what it is.

Financially, we have been prosperous, and this year we enter upon our work with a balance sheet showing a pleasing surplus to the Society's credit.

Our pamphlet too demands a word of mention. Many times have we heard both at home and abroad of our last year's publication being admired for its excellence, by professional men, both practical and theoretical, and such we must consider as no slight compliment to its value, especially to us as students. While passing it may be well to remark that our new members cannot overestimate the advantages to be derived from a careful perusal of its pages; it is an easy thing to cast it aside as having no interest for you, but you will find it not such an easy thing to pick up the gems of research and knowledge which it contains and which you have unwittingly flung away.

Especially marked during the past year is the manner in which the high reputation of this Society has become spread abroad. Members of our circle are engaged throughout the whole continent, numbers of these keep up a constant communication with us, thus showing how highly they value the connection. But chiefly in our own city do we find the influence of the Society felt. It is now recognized as an actual professional institution, and last year it was no uncommon occurrence to be honored with the presence of prominent engineers at our Society meetings. In this connection we might make mention of the valuable paper read and service rendered by Dr. Bryce of the Provincial Board of Health.

Since last year there have been two important changes in the curriculum of the School: the addition of a Fourth Year to the course and the establishment of a lectureship in Sanitary Engineering. The courses as they stood before were without doubt most thorough in their training, and we welcome the extra year to our work as a valuable addition which will make our course in each department at once most thorough and practical. This extra year will be indirectly a benefit to the Engineering Society. It will promote original and individual research, the encouragement of which

is one of the objects of the Society; it will bring an element of more advanced thought and experience into the meetings of the Society, besides being the means of contributing a greater number of active members to the Society. The value of this Fourth Year can scarcely yet be estimated, and we hope the time is not far distant when it will be made a compulsory year of the graduate course.

In reference to the lectureship in Sanitary Engineering. This appointment will, we feel, supply a long felt want in the School; for the wants of the age demand a more scientific and thorough treatment of this branch of engineering. Mr. C. J. Marani, who is appointed to fill the position, has made a special study of Sanitation from both theoretical and practical standpoints; and his being a graduate of the School gives us every reason to believe that this department will not fall below the high standard required by the proud position our School occupies among institutions of its kind.

We are pleased to welcome back to our midst as Fellow in Engineering, Mr. J. A. Duff, B.A., a graduate of Toronto University, and also of the School of Science, who has been away extending his knowledge in the more practical side of engineering, and who has now returned to give the students here the advantage of his increased experience.

Mr. Duff is one of the old war-horses of our Society, having filled the position of President in his final year. He always took an active part in everything connected with student life, and his assistance, which we anticipate will be freely given, will be of the greatest value to the Society by reason of his large experience in executive work.

Before taking my seat I would like to say a few words on a subject which you may consider irrelevant to my position. If so, I would justify myself by the statement that I consider, "Whatever is of interest to the students of the School as a whole, should be of interest to us as a Society," for "Student of the School of Practical Science" and "Member of the Engineering Society" should be synonymous terms.

To-day there is one of our number upholding the standing of Canadian athletes across the Atlantic. We contribute our quota to the support of the baseball, the lacrosse, and the football played on the college campus. We are proud of the part we take and the standing we hold in general college athletics. But we are a distinct institution and we should have a distinct athletic relation. This may appear impracticable at present, on account of the very limited time we are allowed in the curriculum for such recreation. But if we make up our minds to a systematic way in using our present opportunities, and do our best to foster an independent athletic spirit, the developments resulting, I have no doubt, would be far more

encouraging than we even expect. Do not think by my emphasizing this I would wish you to sacrifice the more serious work for which we come here. On the contrary it is for the purpose of making more effective the time we spend over our books and drawing boards, that I advocate the cultivation of this spirit, so that we may enjoy to the fullest extent the motto of our School,

"SCITE ET STRENUE."

R. W. THOMSON.

SANITARY PLUMBING.

By Cesare J. Marani, Grad. S.P.S.

Mr. President and Gentlemen,—Having been requested to read a short paper before you, and, having had occasion to come into contact lately with architects and plumbers in connection with sanitary matters, pertaining more especially to the proper construction and disposition of the plumbing work in dwellings, it occurred to me that I might bring the subject of sanitary plumbing before the Society, and express my views.

But before doing so, permit me to say that the subject of "House Plumbing" has grown enormously within the last few years, and that now it holds a place of no small importance in the planning of buildings. For this reason it is impossible for me to do otherwise than to touch on such points as I consider of greater importance, and which, I fear, are often overlooked by the owner and architect.

Now that an increased desire for thorough sanitation is being manifested by the better classes, the sanitary engineer is often called upon, if not actually to take charge of the plumbing work, at least to plan and advise in the interests of health and economy.

At present this work is largely controlled by the architect and plumber combined, who seem more eager to attain to better results, and much more competent to do so, than they were formerly. Still it cannot be denied that the average architect possesses little or no scientific knowledge whatever on this important subject. Thus clearly demonstrating a fact, that he and the rest of his profession attach too little importance to their responsibilities in connection with the plumbing of buildings, and therefore do not seem to experience for this, that feeling of personal accountability so essential to success, which they do for other and less important sections of their work.

It is hardly necessary to explain that in these, and the remarks I am about to make, I refer not to the average members of "associations of architects," such as we now have in the Provinces of Ontario and Quebec, nor to the Boston Architectural Club, and other Societies in the States; but to the *average*, when we include all who may be said to be practicing as architects, whether considered qualified to do so by these architectural bodies or not, and therefore, in this way considering the *actual* centre of gravity that affects the general public.

Col. George E. Waring, in writing on this subject for the information of architects, as well as others, goes on to say: "I have never applied a water test, under pressure, to work that has been done in a fine house under control of an architect, with any other result, so far as his frame of mind was concerned, than to annoy him by the demonstration of leaks and defects.

"What seems still more remarkable, when I have sometimes thought that I had an architect really converted, when he acknowledged the work to be simple, elegant, safe, cheap, and in every way satisfactory, was that the conversion never lasted. I never found that the example had the slightest influence on him afterwards."

Sometimes we meet with owners, who, while they show all eagerness to consider from a standpoint of comfort, any proposed piece of plumbing work in connection with their house, nevertheless seem afraid to look on the sanitary aspect of the thing; lest the necessity of adopting certain changes or precautionary measures, might rise perforce before them, like the unwelcome ghost of Banquo. In the first place, any additional expense thus entailed, proving little or no obstacle; while in the second, the smallest outlay for the protection of health, would be regarded as a *dead loss*, and objected to in every possible way.

That an architect should ever pander to the wishes of such people, who may be said to be pursuing an Ostrich-like policy, is indeed to be regretted.

Sometimes an owner imagines that his rights as Despot in his own Castle are being encroached upon. It is then the duty of the architect to point out the wisdom of providing for the preservation of health and happiness, not only of himself, but also of others, since we are creatures very much dependent on our neighbors for our sanitary condition.

I knew an architect once, who tried to exonerate himself from all responsibility in connection with a certain piece of "plumbing work," by saying that he had persuaded the owner to employ the best *practical plumbers* in town to do the said work, and that therefore there could be nothing wrong with it.

Obviously the above reasoning was rather sophistical. Who constitute the "best practical plumbers" in a community? Are they men of science as well as clever mechanics? Are they fully entitled, by a sound experience and careful study of their trade, to the full import of such an appellation? I fear not, and certainly much less to that signification which a too confiding public is ever sure to place on such titles. It is a fallacy to imagine that the knowledge of how to handle, cut, and connect pipes, wipe joints, and charge well, of necessity make a man master of the

plumber's trade. And yet I know from experience, that in the great majority of cases, this is regarded as the criterion. It might seem that the impression prevails among a large class of pipe fitters and mechanics, that the possession of a certain number of working tools, together with the *valuable* assistance of a couple of incompetent "shop-boys," a large shingle suspended over the sidewalk, more pronounced in its economy for truth than expense, a few cast iron connections displayed just outside the shop, and lots of gas brackets and other brass fixtures inside, constitutes a man at once a "practical plumber." There are a great many good workmen who are by no means good plumbers, and still a greater number of good plumbers, who are by no means "Practical Plumbers and Sanitary Engineers," as they often style themselves.

It therefore falls back on the architect to provide the soul, yes, the ethereal spirit of theoretical knowledge, and furthermore, to see the same properly and practically incorporated in the work of the plumber. That a man can pursue the plumbing trade without having first thoroughly mastered it in all its details, I consider as the great present evil. Hundreds of dollars have been spent, to my knowledge, in rectifying blunders made by such workmen, of whom it might be said, and this justly, that they had come by their trade dishonestly, because by too short a route. They, of course, little cared what might befall to their work, much less to the health and happiness of others, so long as they might pocket their gains and remain in blissful oblivion as to their moral responsibilities. As an illustration, of what I should term downright practical ignorance, I might give a case that occurred in the town of Brockville, Ont., a few years ago.

One of the so-called "master plumbers," who, previous to his settlement in the town, had worked at his trade for nearly fifteen years in the city of Montreal, and who was therefore looked upon by the simple public as a most desirable man to employ, actually presented a piece of "plumbing work" to be passed and approved of by the Inspector, where a two inch lead pipe, two feet four inches in length, had been bent and used under the closet seat, so as to act as a vent pipe to the closet trap, and at the same time as an overflow waste for the bath tub (see fig. 1). The workmanship, however, was simply perfect.

Not very long ago a case came under my notice in this city, where a long vertical line of soil pipes had choked and blocked up completely. It was thought at first that the servants must have thrown bones and rags, etc., down the closets, but further examination showed that there was nothing in the pipes, save the legitimate house wastes and closet paper.

The plumbers, in erecting the said line of pipes, had used too little

gasket in some of the joints, and none at all in others. The consequence was, that the lead intended for the joints had spurted inside, and in some cases forming regular groups of fingers across the pipes, thus obstructing the passage of paper, etc. The only way this could be rectified was by the tearing down and re-constructing of that vertical line of soil pipes.

On investigation, it was found that the plumber, who was responsible for this, had had no intentions of scamping his work. He had made some extraordinary experiments (by himself), which had convinced him against using a gasket where he could possibly help it. He had come to the conclusion that though a gasket was of great assistance in preventing any loss of lead while pouring a joint, yet from a sanitary standpoint it was objectionable as absorbing and retaining filthy liquids. In the interests of his employers therefore, he had decided to use gasketing only where it was impossible to do without it, and the good faith of the man was manifested

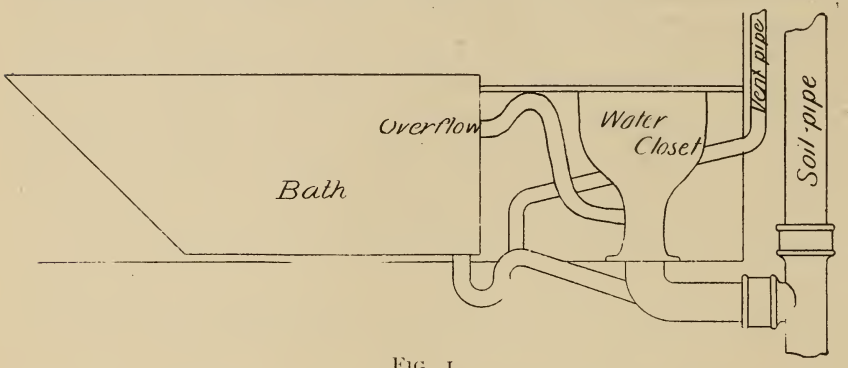


FIG. 1.

in that he had not charged for gasketing, nor for the amount of extra lead he must have lost in trying to fill the joints. It is needless to explain further.

To my mind the house is the unit of sanitary administration. In fact, the whole sewerage system beyond, with its many intricacies and problems, both mechanical and financial, never would have developed, nor even have sprung into existence, but for the dwelling.

We may look upon man's modern habitation, therefore, as the principal source from whence all sewage emanates.

To secure perfect safety to the inmates, while removing at the same time the daily household wastes beyond the outer walls, is then our first consideration.

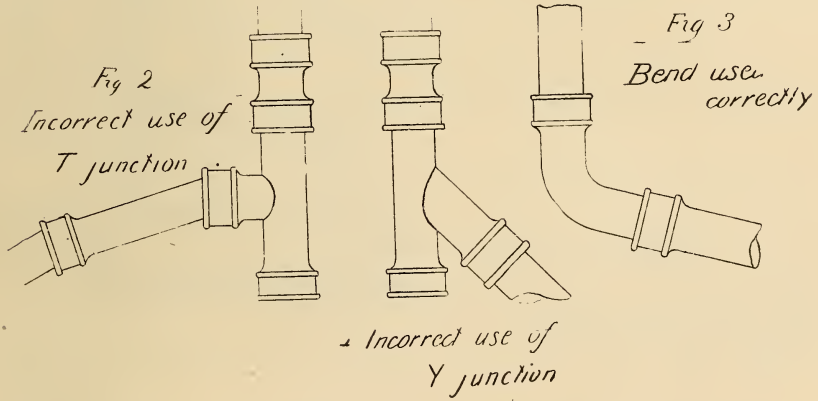
Except where houses are isolated, or strung out in small colonies along concession roads, or again clustered into hamlets or small villages, what is known as the water carriage system, is by far the most efficacious for the removal of the daily semi-liquid and liquid wastes of the dwelling. By

wastes, I mean human excreta, chamber slops, water used for baths, water in which dishes, pots, vegetables, clothes, etc., have been washed, and in fact any water that has been put to a thousand and one of its other uses in a house. We might consider the following as our "plumbing" axioms, and the system with its fixtures, traps, ventilation, and waste pipes, etc., that will conform in the highest degree to them, must perforce be accepted as the best. It is then evident:

Firstly.—That the waste matters generated in the house should be removed at once.

Secondly.—That in so far as it lies in our power, the waste pipe system should be freed from any tendency to retain decomposing matter giving off gaseous products known to be detrimental to health, or these very gases when generated elsewhere.

Thirdly.—That every part of the plumbing should be visible where possible, and conveniently situated as against repairs or accidents.



Fourthly.—That all parts should be of sound materials free from flaws, blemishes, or other defects, and of the kind of material best suited for their special purposes.

Fifthly.—That the whole system should be put tightly together, in the best approved manner, and possessing uniformity in strength and durability.

Sixthly.—That the whole system should be as simple as possible, consistent with convenience, efficiency, and security.

Seventhly.—That the appliances used should be economical, reliable, and adding materially to the comforts of the inmates of the building.

That the waste matters generated in the house be removed at once, can be attained by having as direct and short a line of waste and soil pipes as possible. Every necessary bend in a line of pipes being made by a regular curve, and never abruptly. Wherever the waste and soil pipes run

otherwise than vertically, ample grades should be provided. The smoothness and evenness of the interior of the pipes, along with their size, and also the manner in which they are connected and branched together, having a marked effect on the velocity of discharge.

The use of an inverted T or Y junction for the purpose of effecting a connection between a vertical and horizontal line of pipes, should never be tolerated. The reasons are obvious (see figs. 2, 3). I have actually come across several cases of this unscientific mode of construction.

As there seems to exist, even among writers on sanitation, an uncertainty as to the exact meaning of the terms *house drains*, *soil pipes*, *waste pipes*, etc., it might not be out of place for us to decide upon their proper application before proceeding further. Let a house be given us, and a hundred feet away the street sewer. (See fig. 4.)

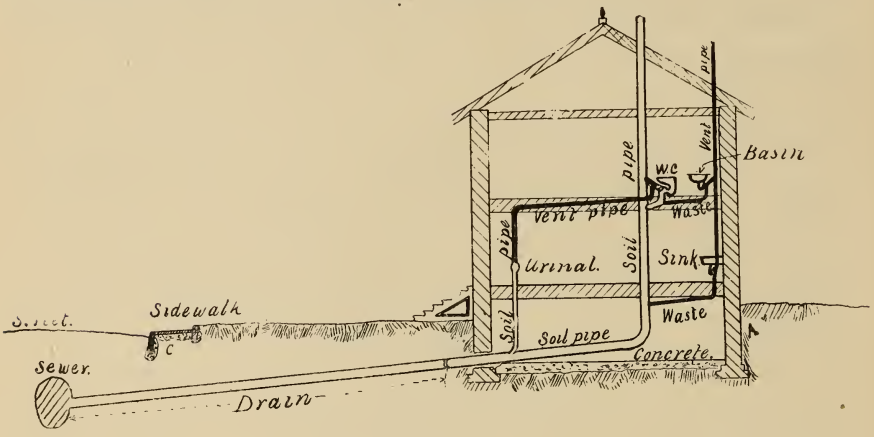


FIG. 4.

Then the system of pipes commencing at the street sewer, running up to the walls of the house, passing through them, and then branching out throughout the building, may be divided into two parts. First, that part outside between the street sewer and the outer walls ; and secondly, that part inside the dwelling. The first is known as the *house drain*, or *drain*, and conveys to the said street sewer all liquid and semi-liquid wastes, and further, all roof and cellar water that may be trapped into it.

The second part, inside the dwelling, is again sub-divided into *soil pipes*, *waste pipes*, and *vent pipes*.

Soil pipes, or soil pipes, are those pipes that carry away human excreta, principally from water-closets, and form the main trunks of the plumbing system of buildings. As such, therefore, they almost invariably receive in addition, the wastes from baths, basins, sinks, tubs, etc., that are conveyed to them by the waste pipes of the system.

Laterals to the main trunks, receiving liquid excreta from hoppers and urinals, are called soil pipes only in a secondary sense, while vent pipes form that part of the system, which does not convey waste waters or sewage of any kind, but is intended to afford free ventilation to the different parts, and to prevent the syphoning of traps. Such portion of the soil pipe as may be found above the highest fixtures, however, and there for no other purpose than that of ventilation, curiously enough retains the name of soil pipe, and does not come under the classification of vent pipes.

We therefore have waste pipes in connection with all fixtures, save those into which human excreta may be emptied. These waste pipes may either enter the house drain independently, or join the soil pipe and discharge their liquid wastes into it.

Soil pipes again may convey excreta alone, or all the wastes of the house to the drain beyond the walls, while at the same time acting as the main ventilating shafts of the system, since their upper ends are always left open and carried well above the roof.

Lastly, the house drain, or simply drain, conveys to the sewer all liquid and semi-liquid wastes placed beyond the walls of the building by the soil and waste pipes.

It must be understood that we have simply considered these terms as applied to house plumbing, and house drains, and not as in the subject of land drainage, nor as in certain of the distinctions used in what is known as the "Separate System of Sewerage."

That in so far as it lies within our power, the waste pipe system be freed from any tendency to retain decomposing matter, giving off gaseous products known to be detrimental to health, or these very gases when generated elsewhere.

From the mechanical side I should say, have the work done by a thoroughly reliable and competent workman, one who knows and realizes the importance of honest workmanship in connecting pipes, in ventilating traps, etc. To place the work in the hands of an admittedly good man, a thorough mechanic in himself, but one who always employs undermen to do his "jobs," and then to rest at ease with the false idea that your share of the work has been performed, and that the workmanship will turn out as desired, reminds me of the story of that simple-minded housewife, who, after placing her marketing of game and fowl on the table of her cottage, and then firmly securing the windows as against the ingress of eagles and other birds of prey, went off leaving the cottage door wide open. During her absence, the fable goes on to say, bears, and other beasts, entered and carried the marketing away.

It is the duty of the architect to determine whether the men actually doing the work are competent or not; and further, he should insist that the work be done by competent men, and competent men only, otherwise all kinds of defects will crawl into the system and prove beyond detection when the work is finished.

Recesses due to badly constructed joints, beads, and strings of solder, or the ends of gaskets in the pipes, all tend to retain filth. Bad connections between vent pipes and traps, destroy the efficiency of the latter. Unnecessary traps, or want of sufficient grade, are again, blunders for which the architect or designer of the plumbing system is alone to blame.

The sizes of the soil pipe and waste branches have also an important bearing on this point. For unless they are so proportioned as to be self-cleansing, the interior surface of the whole system will coat over with a greasy slime, known to give off pestiferous gases ten times more abominable than those found in the main sewer.

Ventilation, while indispensable as a diluter and safe remover of any gases forming or collecting in the system, tends furthermore to arrest, and to a great extent destroy, such a coating. The free ventilation of the whole system, therefore, demands our most careful consideration. This brings up a point still at issue among leading sanitary authorities:—"The whether a trap should be placed on the house drain before it empties into the street sewer, or not." I am inclined to side with those who hold that, while there may be some doubt as to the policy of omitting such a trap in cities, for instance like Toronto, where in the first place the main sewers have been ill constructed, and still more badly ventilated; that, even in the case of only tolerably good sewers, such arguments are only valid that advocate the omission of such traps. It is a fact that such traps arrest the flow of the waste liquids along the pipes, and therefore destroy in a measure their scouring properties, besides reducing the efficiency of carriage of the said liquids.

They also tend to complicate the system by rendering it necessary to introduce a fresh-air inlet pipe, on the house side of their water seals, in order to provide for ventilation.

At the best, this additional pipe, when brought a few feet above the ground, certainly does not add to the artistic effect of a building, and may sometimes prove dangerous to children who may be playing in its vicinity. For since we have the pressure of this obstructing trap on the one side, and sometimes a descending column of water in the soil pipe on the other, any gases thus confined between the two, can only escape by this so called "fresh-air inlet pipe."

Besides, I feel fully convinced that the best and most uniform ventila-

tion for our line of pipes and drains can only be secured when we open one end into the larger street sewer beneath the ground, and the other towards the starry firmament above the roof.

That every part of the plumbing be visible, wherever possible, and conveniently situated as against accidents and repairs.

It is not so long ago since you could not find a single fixture in even the most costly of dwellings, that was not tightly cased in wood. This was particularly so with the water closet. Sanitarians pointed out the dangers to health arising from such a practice, and to-day one can judge of the general improved tone of public opinion on the matter, by just simply looking through any of the numerous descriptive catalogues issued by manufacturers of plumbing fixtures, etc., who, of course, study the demands of the market.

The public taste is certainly tending in the right direction, when marble-topped wash basins, supported merely by open brackets or brass legs, and water closets free from all woodwork save for an oak or mahogany top, are being introduced into the better class of dwellings.

Still we find that certain parts of our system, just as important to the efficient working of the whole, but because of less pretentious appearance than the wash basin and water closet, often seem to have been sadly neglected in the apportionment of the plumbing expenditures. I refer to the all important kitchen *sink*, and servants' hopper.

One often finds that while care and judgment are manifest in the selection and arrangement of the other fixtures of a house, any cheap concern has been accepted to pass for the kitchen sink. But, as if instigated by some secret feeling of doubt as to the justifiableness of such a course, and as if ashamed of the uncanny result, we find that the owner, or architect, has had it securely encased in carpentry.

Not only are the waste pipes, traps, and joints thus cut off from view where they most require watching, but the dark foul space underneath the sink is invariably utilized for the storage of cooking utensils, mops, rags, old shoes, coal oil cans, scrubbing brushes, boot blackening, grease, and other matter certainly never calculated to aid sanitary conditions.

The same might be said of the servants' hopper, which should be free from all wood work.

It should be placed where a quantity of light and ventilation can be had at all times, and not carefully and gingerly confined to a little cubby hole somewhere beneath the staircase, or in a dark unventilated closet, where it works mysteriously in a mysterious darkness.

A word with regards to the soil pipe in the basement. The best practice of the day is justly tending to do away with the burying of the soil

pipe within the house, and underneath the concrete or wooden flooring of the cellar. That this was a pernicious habit it is needless to explain.

Should an obstruction of any kind take place within the house, it might necessitate the tearing up of yards and yards of flooring. And then again, a line of pipes so placed could not be tested and examined as effectually as if raised clear of the floor, and open to view. Leaks and other imperfections announcing their presence, and being detected much more readily, in the latter case.

That all parts be of sound material, free from flaws, blemishes, or other defects, and of the kind of material best suited for their special purpose.

In the last few years wrought iron has been introduced in the plumbing of buildings, under what is known as the "Durham system of house drainage."

The great advantages claimed by Mr. Durham, a civil engineer, for his system being that "wrought iron pipes are elastic and cannot be broken, and that when lengths are screwed together in a wrought iron coupling, the joint is as strong as any other part of the pipe; furthermore, that they will stand up vertically from a solid base to the height of any building without lateral support, and being much lighter are more easily handled."

Mr. Durham goes on to say:

. . . . "By the use of wrought iron pipes and screw-joints we construct a drainage apparatus within the building, which is gas and water tight as regards the joints; rigid, yet elastic; entirely independent of walls or floors for support, and absolutely invulnerable. As a structure it will last as long as any building will stand, and without any outlay for repairs." The thorough reliability of screw joints, and the uniformity of thickness and strength which can only be secured by the use of wrought iron soil pipes, seem to be the chief points in favour of this system.

Cast iron pipes, when of sufficient thickness, make good soil pipes. This is easily determined by their weight, and the only quality, known on the market as "extra heavy," can be safely recommended.

Even this class of pipe sometimes displays a marked unevenness of thickness on the opposite sides of a cross section, and therefore being in its weakest part no better than light pipe.

The bells on the "extra heavy" have sufficient strength to stand the caulking necessary to insure a trustworthy joint, which is not the case with the lighter class of pipes.

Lead is of course unfit for soil pipes, and should not be used even for waste pipes when a diameter of over two inches is required. For smaller waste and vent pipes, lead can be used to great advantage, for it bends, cuts, and manipulates easily.

The thickness of any lead pipe, or in other words the weight per running foot, should always be determined with reference to the work it is intended to perform.

Cast lead traps are objectionable, drawn lead being preferable for that purpose.

Traps and pipes made by hand of sheet lead, are of course out of date.

Brass is also used in ferrules and in the best forms of traps. It is also used, either polished or nickel plated, for those portions of the plumbing system that lie exposed in connection with the better class of fixtures.

Cast brass traps, such as the "Elliptic" and "Progress," manufactured by the J. L. Mott Iron Works Co., New York, are among the very best and most efficient, and to my mind a great improvement on lead traps.

Glass, when used as a portion of a trap, is objectionable, as it is so liable to break by a number of causes.

With regard to the fixtures of the system, I might say that the water closet should be of earthenware or porcelain ware, in one piece, and connected to the soil pipe by the brass flange method. Any of the numerous washout closets are good, though the more recent siphon closets, as for instance the Sanitas, and also such improved hopper closets as the "Trent wash down," are considerably better. For the respective advantages of these I must refer you to works on the subject. Baths and basins should be of porcelain ware. When a bath of this kind should be found too expensive, a "porcelain-lined iron bath" of the Imperial class will answer well; and hoppers and kitchen sinks should be preferably of English brown ware, or Yorkshire ware. Porcelain-lined wash tubs are good, though they do not last like the porcelain ones.

That the whole system be put tightly together, in the best approved manner, and possessing uniformity in strength and durability.

This comprises a very wide and important field, for, not only must the mechanical part, *i.e.*, the cutting, bending, fitting, wiping, soldering, caulking, etc. (which go to make the Art as distinct from the Science of plumbing), come under consideration singly; but the whole work must be previously thought out, and arranged with a view to uniformity of strength and durability of the entire system. While the most approved practical methods may be understood by the scientist, it takes the practical workman to carry them out in part or in whole, and for this fact a good mechanic is indispensable. For the tightness and safety, then, of our system, we have to depend on the mechanical ability of the men we employ. No matter how scientific and commendable our plans, if the workmanship prove below the mark, miserable or defective, we must expect to meet with disappointment or failure. I therefore fail to see the force of arguments,

seemingly based on the assumption that the science is everything, and the art a very secondary portion of our subject.

That this was the tendency among sanitarians in Great Britain, when sanitary plumbing received a fresh impetus some ten years ago, may be seen from the following remarks by S. Stevens Hellyer:

"If I were going to build a house for my own occupation, I should prefer the plumbing work to be done by the man who was more skilled in the science than in the art of his craft—that is to say, I should prefer a poor joint wiper to a clever one, providing that the former knew what the latter did not, viz., how to select and arrange the traps, pipes, and fittings, so that they would be 'self-cleansing'; what kind of traps to select, and how to ventilate them so that they would not lose their water seals, how to ventilate the waste-pipes, soil pipes, and drains, so that the air within them should be constantly changed—know, in short, how to execute his work on sanitary principles."

In these days of *specializing* and *high speed*, it would be almost impossible to find a man who might be considered equally competent to lay out both a system of plumbing for you, and to construct the same from cellar to attic with his own hands. We do not expect it. We do not want it. But we do insist on the joints being well wiped, the bends properly made, and the bells tightly caulked.

That the whole system be as simple as possible and consistent with convenience, efficiency, and security.

I think this appeals to all scientific minds, though I know of certain plumbers in this town, who, if judged by their works, certainly could not be said to agree with me in this respect.

However, I am glad to notice that there is a strong tendency towards simplification in plumbing work throughout this Continent, which will tend to make good plumbing more popular and less costly; and I firmly believe that a judicious use of anti-siphonic traps will prove one of the great factors in simplifying the house-plumbing of the future.

While I do not admit that they are preferable in *every* case, and for *all* fixtures, still I will say this, that the better kinds are more trustworthy, and less liable to get out of order, than architects and sanitarians imagine; and further, that for certain cases they are undoubtedly the only traps that meet the requirements to any degree.

Owners should be advised against such fads as, for instance, having a basin, or other fixture, placed in some remote corner of the house, and at a considerable distance from the main pipes of the plumbing system. Such arrangements greatly increase the number and complication of pipes, not to speak of the cost, and the fact that security is being sacrificed, in a measure, for trifling convenience.

At present the vent-holes in water closet fixtures are made too small. A water closet trap should be vented with nothing less than a 3-in. vent pipe, and running traps under basins, etc., should be vented with vent-pipes at least of the same size as their wastes, and in most cases a little larger diameter is preferable.

Sanitarians seem to forget that while ventilating pipes are useful in preventing the siphoning of traps, their principal work is to ventilate. Experiments have shown that they cannot do this *effectively*, unless they are made large enough.

As sink wastes have a tendency to be too large, we may therefore expect to see, in the near future, the diminution of the diameter of certain wastes, and the enlarging of certain ventilating pipes, and thereby the increasing of the efficiency of both.

That the appliances used be economical, reliable, and adding materially to the comfort of the inmates of the building.

In conclusion, I may say that the number of fixtures in a dwelling should be kept down as much as possible. Not merely from a consideration of economy, but from the more important standpoint of health. The oftener traps are used the better. Where a house has a large number of basins, some may be rarely used, and their traps are liable to evaporate away. Wherever overflow-pipes can be done away with, it is for the better.

Basins provided with the Boston plug, which acts both as a plug and as an overflow waste in itself, are the best fixtures of the kind on the market to-day. Wastes from refrigerators, cisterns, safes, etc., of course should never be connected directly to the plumbing system, but all these secondary points are well treated in any of the more recent books on the subject.

After all, the underlying principle of "sanitary plumbing," is to secure such an arrangement of pipes, traps, and fixtures, that any solids, liquids, or gases can readily and speedily find an entrance into the plumbing system, at any of the openings in the house; but that, having once gained an entrance, they can never-more return to injure the health of the inmates of that dwelling. When this fundamental principle is thoroughly understood, it should not prove a hard task to determine upon a Sanitary system of house drainage.

HOT WATER HEATING.

By W. H. Shillinglaw, Brandon, Man.

In writing this paper, I do not pretend to give anything new on the subject of heating by hot water; but only describe the system as it has come under my own notice and direction, with some of the principles on which it works.

First:—The different systems used for heating buildings, the principal of which are: Hot Air, Steam, and Hot Water.

The most common method of warming buildings, and perhaps the most economical, where the buildings are small or where a uniform temperature is not required throughout the building, as in churches, schools, and dwellings, is the hot air furnace. This consists of a fire-box cased with iron or brick, enclosing a chamber for heating air, from which pipes carry the heated air to the various apartments.

Steam heating is now only used where there is a steam plant in connection with the building to be heated, and where exhaust steam from the engine can be used. The apparatus consists of a boiler to generate the steam, and the necessary pipes to convey the steam to the coils or radiators in the building.

Hot water is generally used here, where a complete system of heating is required, and is fast taking the place of other systems even in the smaller buildings. The apparatus consists of a heater and the necessary flow and return pipes or mains, etc., to connect with the coils or radiators in the apartments to be heated.

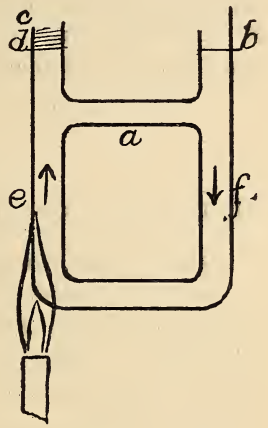
There are two causes for the circulation of water in vessels: one—the subtraction of heat; the other—the addition of heat. I have heard of one other (I will give it to you for what it is worth)—water itself won't expand, but the air contained in the water expands and thus causes circulation.

The first may be observed in a closed glass vessel filled with hot water and allowed to cool, when the particles in contact with the sides of the vessel become cooler by giving off their heat to the surrounding air. Cold water is denser than hot water, and falling, displaces the hot water, which rises up the centre of the vessel.

The second may be observed in an ordinary test tube heated over a flame, where the heated particles rise in the centre of the tube and are replaced by the cooled particles falling. In this case, heat, or its mechan-

ical equivalent, is the force employed to overcome gravity, and is the cause of circulation of hot water in a system of pipes.

A simple apparatus, as in figure, will illustrate the circulation of water in a hot water system, in which *e* and *f* represent the flow and return pipes; *c*, expansion tank; and *cd*, head caused by expansion. The velocity of the flow of water in a system of pipes, is due to the head caused by the expansion of the water in the heater and the pipes. This is the theoretical velocity, and allowance must be made for friction in the pipes, bends, valves, etc., and loss by entry into pipes.



For the flow of water into and through pipes, loss of velocity from friction, bends, etc., I will refer you to Hydraulics.

Baldwin (pages 42 and 43) gives diagrams by Dalton to show the expansion of water between 40° and 212°, for a height of 10 ft., and the velocity of the flow of water in feet per second, when the height from which it falls is known. These diagrams are used together. For example, take an apparatus 10 ft. high in which the water enters the flow pipes at a temperature of 182°, and returns at 162° to boiler. What should be the greatest possible velocity of the water in the flow pipe?

By diagram A for a temperature of 182° we have a head of 3.49 in.; for a temperature of 162° a head of 2.69 in., or a difference of head of .80 in. By diagram B, approximating .80 on the vertical scale, a horizontal line drawn from it will cross the curve where the 2 ft. velocity line cuts it; or, for a head of .80 in., we have a theoretical velocity of 2 ft. per second. Having made the necessary allowance for friction, etc., from this velocity, the diameters of the pipes necessary to deliver the required amount of water to the radiating surface can be obtained.

In planning a hot water system, the first thing to consider is the radiating surface required, and this can only be decided on from the nature of the outside walls of the building, condition of windows and doors, and we must have a good conception of the amount of heat lost through windows, walls, etc., and the amount of heat given off by the radiating medium. For the methods of proportioning radiating surface, I give the following rules, and will refer you to Baldwin's Hot Water Heating, for further information that you will require.

The common method used is to allow a percentage of one in. pipe to cubic space. Baldwin gives the following rule (page 86): "Divide the

difference in temperature between that at which the room is to be kept and the coldest outside atmosphere, by the difference between the temperature of the steam (or water) pipes and that at which you wish to keep the room, and the quotient will be the square feet or fraction thereof of plate or pipe surface that is the equivalent of each square foot of glass or its equivalent in transmitting power."

For example, t = required temperature of room.
t^1 = outside temperature.
T = temperature of water in radiator.

Then $\frac{t-t^1}{T-t} = r$, ratio of radiating surface to glass surface. Say $t = 70°$, $t^1 = 30°$, $T = 140°$, then $r = .57$.

But for a climate where a thermometer reaches as low as $-40°$, it is necessary to have a greater allowance for this ratio, which may be obtained by giving t^1 a value 0°, which will give $r = 1$, for a temperature of 140° of water in radiator, so that for temperatures below 0° the heat of the water in pipes may be increased, or for $-40°$, T would be $\frac{t-t^1}{r} + t = 1$ the temperature of water required in radiator.

To this ratio of one of pipe or plate surface to one of glass or its equivalent of wall surface, from 10 to 50 % must be added for warming air admitted accidentally, and for loss of heat by other sources than walls and windows, and the allowance to be made will depend on the character of the building and the judgment and experience of the designer. In this method, from 7 to 12 feet of wall surface are taken as equal to one foot of glass surface, and the amount of radiating surface is computed from glass surface.

In *The Engineering Record* of Nov. 29 and Dec. 13, 1890, in an article by R. C. Carpenter, of Ithaca, N.Y., the following formula is given:

$s = \frac{7}{15}\left(\frac{1}{70}c + 11w + 1.5g\right)$, in which
s = radiatory surface required.
c = cubic contents of room.
w = no. of windows and doors.
g = glass surface. The fraction $\frac{7}{15}$ is obtained as follows:

$\frac{2}{3}\left(\frac{t-t^1}{T-t}\right)$ in which $t = 70°$, $t^1 = 0°$, $T = 170°$.

But this is for a climate where 0° is considered a fairly low temperature, or for temperatures experienced here.
$t = 70°$, $t^1 = 0°$, $T = 140°$, then $\frac{7}{15}$ becomes $\frac{2}{3}$. (See *Engineering Record* of above dates).

By the "percentage" method, a certain percentage of the cubic

capacity of the room is taken in one inch pipe. This is the simplest and most commonly used here. The usual allowance is 8 to 10% for ground floors, 6 to 8% for first floors, etc., depending altogether on the kind of building and location of the rooms. I give an example in illustration of the different methods, which will show how they will correspond with each other; in some cases they give widely different results.

	Baldwin. $S = 1.10$ to $1.5g$.			Carpenter. $S_1 = \frac{2}{3}(\frac{c}{70} + 11w + 1.5g)$	Per cent. Method. $S_2 = 10$ to 8%. *3 ft. of 1 in. pipe = 1 ft. surface.*
No. of Room.	*Cu. ft.* $= c$.	g	S	S_1	S_2
No. 1	2093	45	68	72	69
No. 2	1990	36	62	62	66
No. 3	2210	72	96	108	74
No. 4	3510	72	99	120	117
No. 5	1729	130	170	162	58
No. 6	2080	67	67	98	69

These rooms are on first floor, and have a west and south front, but the calculations are based on ground floor allowance. The walls are 17 in. solid brick, back plastered, strapped, with plastered three-coat work. Frames are boxed and well packed; glass, plate (glass surface is given for size of opening in brickwork); ceilings 13 feet. The above table will show some of the difficulties in proportioning a hot water system, and shows further how much depends on good judgment and experience in the use of formulæ of any kind.

By the "percentage" method, which deals only with cubic capacity, allowance must be made where the cubic capacity and outside wall area are disproportionate; take, for example, rooms Nos. 4 and 5, in which the proportion of outside wall area to cubic capacity is $\frac{1}{22}$ and $\frac{1}{5}$ nearly, yet this method gives 117 and 58 feet as heating surfaces required, or the room with least cooling surface has the greatest heating surface. Of course in practice No. 5 would be given more surface, but No. 4 would most likely be unchanged, the result in both cases being wrong.

By the other formulæ this is reversed.

The following conclusions may be drawn from this table:

1. The percentage method gives a quantity which may be too large or

too small in itself, but from which, by the use of good judgment, the nearly correct amount of heating surface can be decided.

2. Carpenter's formula gives the heating surface based on outside and inside temperature, temperature of surface, number of openings, cubic capacity, and glass area; but omits actual wall surface, which he says will have but little effect.

3. Baldwin's formula gives heating surface, based on outside and inside temperature, temperature of surface, glass area, with wall area reduced to glass area; but omits the cubic capacity. This leaves the value of r to be chosen by the designer, and experience will enable almost any one to put a sufficiently accurate estimate on this item.

I am not prepared to say which is the best method of the above three, but I think Carpenter's would give the best results, as it deals with the quantities which will most affect the heating of a building. I know of no work proportioned by any except the percentage method. For upper floors, by the percentage method, a decreasing scale of values is used as the height increases. By the other methods, the amount of surface is not decreased; but the amount of water supplied is regulated by decreasing the size of pipes, and inlets and outlets of radiators. There is little use of my giving you the methods of doing this, as the diameters of inlets to radiators, coils, etc., are fixed by commercial sizes—1¼ in. being the common size. For smaller sizes, these require to be reduced by bushing.

Diagrams are given by Baldwin (chap. 14 of Hot Water Heating) for the purpose of determining the diameters of supply pipes to radiators. In practice, the hot water fitter uses his own judgment as to different sizes of radiators and heights above boiler. Of course in running horizontal mains, allowance must be made for length of main, connections, etc.

The main pipes and systems of piping used in the warming of buildings by hot water may be classed under two heads, as simple or single circuits and compound circuits.

A single circuit system has no branches, but the flow and return pipes supply but one coil or radiator.

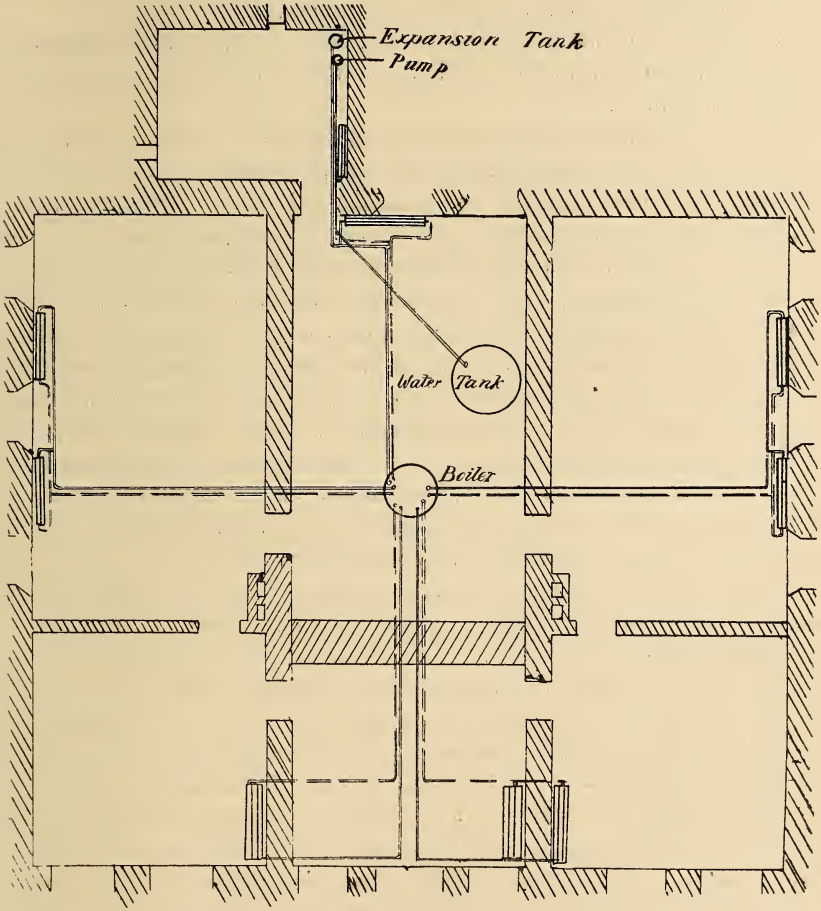
A compound circuit system has branches taken off a main supply pipe to feed the coils and radiators.

A single circuit system is of course the easiest to put in, as in any case the circuit cannot but work; but will not in a compound circuit, unless the main is of sufficient capacity to supply the circuit throughout. There is one danger in this system, of the water taking the shortest circuit, which can only be overcome by proper proportioning of the entire system.

I will give a short description of the accompanying drawing.

This is to all intents a simple circuit system, although two radiators are

supplied from one flow pipe, but as the branches are of equal length and radiators are on the same level, there is no difficulty in the supply. The boiler is a Gurney of 3000 feet of one inch pipe capacity. Radiators used are Gurney's make. The boiler is located in the basement in the centre of building, which is only one storey. The expansion tank is in room at



LAND TITLES OFFICE.

rear, and about twelve feet above boiler. The drawings will give you all information as to size of pipes, etc., each circuit having draw-off cocks. The building is constructed very similar to an ordinary vault—walls 24 inches thick, with hollow space, and plastered directly on brickwork; roof, a three ring brick arch over each section. All frames and doors are iron. Height of ceiling 16 feet.

In the Fleming block this system was put in by the "percentage" method, the contractor being required to guarantee the boiler capacity and pipe system. This method of putting in hot water apparatus is generally adopted here, and which, I think, should be done away with as soon as possible; although it takes a great deal of the responsibility out of the architect's hands, yet it seldom gives satisfaction to anyone. Even if the radiating surface is properly proportioned, the supply may not be sufficient for the work to be done on account of mains, etc., being too small.

I had this difficulty in connection with this work. Taking mains Nos. 1, supplying wholesale department, and 2, supplying west section of building; wholesale, 966 feet of surface; west section, 1352 feet. It was the original intention to supply these by a 3 inch and a 4 inch main respectively. This was altered, a 4 inch main being now used for wholesale, and about 1176 feet of west section being put on a 4 inch main and the remainder on a 2 inch. The reason for putting in the smallest mains that will supply the system, is to save money in construction—one of the evils of allowing the hot water contractor to proportion his own piping. The result of insufficient main supply will show itself in coal consumption, when required to force the system in very cold weather. In a country where the only hot water engineers are contractors and competitors as well, it shows how important it is that the architect should make this ever increasing demand for heating, one of the most important branches of his work.

In these two systems, all mains are valved with Peet valves at boiler, and provided with draw-off cocks, so that any one main can be used independently of the others. Each rising line of pipe, supplying radiators, from main is valved and provided with draw-off cocks as well, giving almost complete separation for any circuit or branch circuit. The boilers used are the Plaxtow Boiler, made in Galt by MacDougall; Gurney radiator and inch pipe coils giving heating surface. I am unable to add anything regarding the results to be obtained from this system, for two reasons: (1) The apparatus was put in in the middle of winter, before the building was plastered, and during our coldest weather only a small section was in use. (2) We have had no cold weather to give, what is considered here, the boilers a good trial. I should like to have been able to have attached such results as, coal consumption, temperature from radiators, including their location, supply, etc., difference of temperature between flow and return, etc., etc., as these taken together with drawings would give a better idea of what is required in a hot water system, than a mere paper as to what should be put in.

THE FUNDAMENTAL PRINCIPLES OF MECHANICS.

By J. A. Duff, B.A., Grad. S.P.S., Fellow in Engineering.

In childhood, a very definite conception is formed of matter, space, and time. It is observed that bodies which are not fixed to the earth frequently change their position relatively to it, and that the earth and other bodies are continually changing their position in space.

The change of position of a body is called its displacement, and is measured by the distance between the two positions of the body. When a body is being displaced, it is said to be in motion. The term motion involves the time occupied by the displacement as well as the space traversed. Two motions are not equal unless both the displacements and the times occupied by the displacements are equal. When a body is moving uniformly, the displacements during equal intervals of time will be the same. It is, however, observed that bodies do not always move uniformly, and enquiry should then be made into the cause of any change of motion which may take place.

If, by our own exertions, we change the motion of a body, we ascribe the cause to our muscular power or force; accordingly, the term *force* is applied to any cause which may change the motion of a body.

The science of Dynamics is the investigation of the relations existing between the forces acting upon a body, the body itself, and the motion which would ensue. On account of our ignorance of the exact nature of the molecular actions which take place in natural bodies, the complete solution of the problem of Dynamics is impossible. It has accordingly been found necessary to make certain assumptions concerning the constitution of matter, by means of which a solution of the Dynamical problems is possible. Although these assumptions are only approximately true, the results obtained are sufficiently accurate for most purposes. For example, the deformation of ordinary solids under ordinary forces is very slight, and it is sufficient in many cases to assume that there is no deformation at all; thus all reference to molecular action is avoided, and yet the results are sufficiently accurate.

Before entering upon the whole question of Dynamics, it is customary to make a special study of the relations existing between forces without reference to the ensuing motion, and a study of motion without reference to the cause. The latter of these investigations is called *Kinematics;* the former, *Statics.*

Statics literally means the science of equilibrium, but its province has been enlarged so as to include all investigations concerning force in which the motion of the body is not considered.

The term *Mechanics* is frequently employed to embrace the three sciences, Statics, Kinematics, and Dynamics. It is used in this sense in the title of the present paper.

Dynamics being the investigation of the relations existing between force, matter, and motion, and motion involving both time and space, dynamics involves time, space, matter, and force. These may be called the four fundamental ideas of Dynamics.

In Statics, the idea of time is eliminated, and we are concerned only with force, matter on which force acts, and space in which matter exists, and through which force acts. In Kinematics, the idea of force is eliminated, and we are concerned only with matter, motion of matter, and space in which motion takes place and matter exists. These results may be tabulated as follows:

MECHANICS (Sometimes also called Dynamics).	*Statics*, treating of matter, space, and force.
	Kinematics, treating of matter, space, and time.
	Dynamics, treating of matter, space, time, and force.

The ideas of space and matter are never entirely eliminated, but each of the above sciences is subdivided according to assumptions which may be made regarding matter and space. Thus there is the Statics, Kinematics, and Dynamics of a particle, of a rigid body, of an incompressible fluid, or of an elastic solid or fluid body; and each of these is treated separately, according as space is assumed to consist of one plane, of a series of parallel planes, or of indefinite extension in every direction.

KINEMATICS—*motion.*

The rate of motion of a body is called its *velocity*, and is measured by the displacement per unit of time. Space and time are concrete quantities whose units of measurement may be chosen independently. Hence the expression for the velocity of a body will vary with every change made in the unit of space or time, and the velocity will not be completely given unless the units of time and space are both given. It follows at once that two velocities cannot be combined in any way unless both are expressed in the same units of time and space.

Displacements measured in any given direction must not be considered as identical with the same lengths measured in another direction. Therefore, in order that a displacement may be completely defined, its direction and sense, as well as its magnitude, must be given. In the same manner,

a velocity (which is the ratio of a displacement to a time) must be given in magnitude, direction, and sense in order to be completely defined.

Any quantity which may be specified by magnitude, direction, and sense is termed a *vector quantity*. Any vector quantity may be represented by a finite straight line, because magnitude, direction, and sense may be thus represented. Displacements and velocities, being specified by magnitude, direction, and sense, are vector quantities, and may be represented by finite straight lines.

If the motion is such that the velocity is always the same, it is said to be uniform or constant. If the velocity changes from time to time, it is said to be variable.

The average velocity during any interval is the ratio of the displacement to the interval. If the velocity vary continuously, that is to say, if in passing from one value to another it successively assume every intermediate value, then the shorter the interval the less will be the difference between the extreme velocities; and the less, also, the difference between the actual velocity and the average velocity during the interval. The interval may be made so small that this difference will be less than any assignable quantity; in other words, if the velocity vary continuously, by taking the interval of time indefinitely small, the velocity during that interval may be considered uniform, and the actual velocity may be expressed by the average velocity during the interval. Accordingly, if δs is the distance traversed during a time δt, the velocity is expressed by $\frac{\delta s}{\delta t}$.

The rate of change of velocity is called *acceleration*, and bears the same relation to change of velocity that velocity bears to displacement, or change of position. Acceleration may be either uniform or variable; the average acceleration during any interval is measured by the ratio of the change of velocity to the interval. Since an acceleration may be specified by magnitude, direction, and sense, it is a vector quantity, and may be represented by a finite straight line.

One of the most important problems in kinematics is the composition of velocities, or the determination of the single velocity, which is equivalent to two or more velocities acting simultaneously. This single equivalent velocity is called the *resultant*. But before determining the resultant velocity, let us examine the similar problem for displacements.

The displacement of a body depends only on the velocity and the duration of the motion, and not upon the time at which motion occurs. Accordingly, the displacements under consideration, although occurring simultaneously, may be supposed to take place in succession, in any order.

Let the vector of that displacement which is supposed to take place first be drawn; from its extremity let the vector of the second displacement be drawn, and so on; in this manner a polygon is formed of the displacement vectors. The resultant displacement is evidently represented by the straight line joining the initial to the final point of this polygon.

In like manner, velocities may be supposed to act in succession; and when all the velocities have acted for the given interval of time, the body will be in the same condition as if the velocities had acted simultaneously. Accordingly, if the vector of one of the velocities be drawn, and from its extremity the vector of another, and so on, a polygon will be formed of the vectors of the several velocities, and the straight line joining the initial and final points of this polygon will be the vector of the resultant velocity.

Again, if it is desired to find the resultant of several accelerations, construct the vector polygon for the accelerations, and the straight line joining the initial to the final point will be the vector of resultant acceleration.

STATICS—*force.*

A force is completely specified when its magnitude, direction, sense, and point of application are given. In so far as it involves magnitude, direction, and sense, a force is a vector quantity, and may be represented by a vector line.

The vector of the resultant of a set of forces is (by the analogy of other resultant vectors) the straight line joining the initial to the final point of the vector polygon. This theorem, which is the basis of the science of Statics, is frequently deduced by means of Dynamical considerations. According to Newton's Second Law, "change of motion is proportional to the impressed force, and takes place in the direction in which the impressed force acts." In other words, a velocity or change of velocity is the same in direction and sense, and is proportional in magnitude to the force which causes it.

It follows that the vector of a velocity may be made to represent a force by simply changing the unit of measurement. Hence all theorems concerning velocity vectors are true also for force vectors. But it has been shown that the vector of the resultant velocity is given by the straight line joining the initial to the final point of the vector polygon. Accordingly, if the scale be changed from velocities to forces, the vector of the resultant force is given by the straight line joining the initial to the final point of the vector polygon. If the direction of the forces all pass through one point, the resultant will evidently pass through that point; but if the directions of the forces do not all pass through one point, a further investigation will

be required to determine a point on the line of action of the resultant—an investigation for which there is not space in the present paper.*

If a set of forces are in equilibrium, there will be no change in the motion of the body on which they act. Recurring to the Dynamical law, that "change of motion is proportional to the impressed force," it follows that in order to have equilibrium, or no change in the motion, the set of forces must be reducible to a single resultant, which is zero.

DYNAMICS—*force*, *mass*, *motion*.

Although such properties of matter as the size, configuration, and elasticity of bodies are considered in Statics and Kinematics, the *quantity of matter* in the body is not taken into account. The *quantity of matter* in a body is called its *mass*, and is measured by the motion produced by a certain force. Hence, it is only in Dynamics, where force and motion are considered conjointly, that any reference could be made to *mass*.

The relations known to exist between time, space, matter, and force are usually expressed by certain physical laws, known as Newton's Laws of Motion. The proof of these laws rests in the fact that every logical deduction from them, which man has been able to test by experiment or observation has been found to be true. It is upon these laws that the science of Dynamics should be based.

The First Law is: "*Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it may be compelled by impressed forces to change that state.*" If no forces act on a body, it will continue to move with whatever motion it had at the moment when all forces ceased to act upon it. The algebraic expression for the First Law is:

$$\text{If } F = O, \text{ then } \frac{ds}{dt} \text{ is a constant,}$$

$$\text{or, } \frac{d^2s}{dt^2} = O.$$

The Second Law is: "*Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.*" The term *motion* is not employed here in the same sense as in Kinematics, where the ideas of force and mass are not introduced, but signifies the *quantity of motion*, or the momentum of the body, which is measured, according to Newton, by the product of the *mass* and the *velocity*. Change of motion will be measured by the change in this product, or, if the mass remains constant, by the product of the mass into the change in the velocity.

*See paper on Diagrams.

Again, if F is the measure of a force acting through one unit of time, Ft will be the measure of the same force acting through t units of time, because the effect of any force is proportional to the time during which it acts. Therefore, according to the second law, $m_1v_1 - m_0v_0$ is proportional to $F\ (t_1 - t_0)$ when m_0v_0 is the quantity of motion in the body at the time t_0 and m_1v_1 the quantity of motion at the time t_1. By suitably choosing the units of *force* and *mass*, the above proportion may be reduced to an equation. If the mass remains constant during the interval, and the units be suitably chosen, then

$$m\ (v_1 - v_0) = F\ (t_1 - t_0) \qquad (1)$$

is the algebraic expression for the Second Law. If the body start from rest at the beginning of the interval, the equation reduces to

$$mv = Ft. \qquad (2)$$

In Dynamics there are two systems of units for measuring *force* and *mass*, and this sometimes gives trouble to beginners, though not on account of any real difficulty. Both systems are chosen in such a manner as to reduce the expression for the second law of motion to an equation. If, for simplicity, we consider the motion of a body starting from the rest, the units are made subject to the condition

$$mv = Ft \qquad (2)$$

If the unit of each quantity be taken, this equation becomes, unity equal to unity. The units of any three of the quantities may be chosen arbitrarily; that of the fourth will then be determined in accordance with the above condition. The unit of time may be taken as one *second*, the unit of distance as one *foot*, and therefore the unit of velocity as one *foot per second*. Thus, if the unit of mass is taken as the *imperial pound*, the unit of force must be (equation 2) *that force which, acting on one pound of matter during one second, generates in it a velocity of one foot per second*. This is called the Absolute Unit of Force.

The most familiar of forces, as well as the one which furnishes the most convenient means of measuring force, is the Attraction of the Earth. It is most natural that the attraction of the earth on some definite quantity of matter should have been chosen as the unit of force. The quantity of matter thus selected in the British countries is the *imperial pound*—the same body which in the Absolute system is taken for the unit of mass. With the pound for the unit of force, and the same units of space and time, the unit of mass must be (equation 2) *that mass which, when acted upon during one second by a force of one pound, will acquire a velocity of one foot per second*. This is called the Gravitation Unit of Mass.

Experiment has shown that any body falling unresisted to the Earth will

acquire in one second a velocity which may be taken as 32.2 feet per second. Accordingly, if a force equal to the attraction of the earth on one pound (which is the Gravitation unit of force) act upon one pound of matter for one second, it will generate a velocity of 32.2 feet per second. Or, if the same force act upon a mass of 32.2 pounds, it will generate a velocity of one foot per second. This is the condition to be fulfilled by the Gravitation Unit of Mass, which is therefore taken to be 32.2 pounds. Again, if a force equal to $\frac{1}{32.2}$ of the attraction of the earth on one pound act on a mass of one pound during one second, it will generate a velocity of one foot per second. This is the condition to be fulfilled by the Absolute unit of force, which is therefore taken to be $\frac{1}{32.2}$ of a pound. Hence in the Gravitation system the unit of force is one pound, and the unit of mass is 32.2 pounds; in the Absolute system the unit of force is $\frac{1}{32.2}$ of a pound, and the unit of mass is one pound.

It must be remembered that the word *pound* is used in two different senses—as a measure of mass, and as a measure of force.

It may also be remarked that the units of the Gravitation system are each 32.2 times larger than those of the Absolute system, and that in both systems the unit of mass is 32.2 times larger than the unit of force.

In the equation $m(v_1 - v_0) = F(t_1 - t_0)$ (1)

If $F = 0$, then $m(v_1 - v_0) = 0$ (3)

That is to say, if there be no force acting on the body, there will be no change of motion or momentum, and the body will continue in its state of rest or of uniform motion in a straight line. Thus the First Law of Motion is the particular case of the Second, in which the impressed force is zero.

In the case in which the applied force changes the direction but not the magnitude of the motion, equation (1) apparently fails to represent the Second Law of Motion. The left-hand side vanishes because v is algebraically equal to v_0, but the right-hand side is evidently not equal to zero. The explanation is that v is a vector quantity, and involves direction as well as magnitude. If v is to be used in the restricted sense of an algebraic quantity, then F must be restricted to *the resolved part of the force* in the direction of the motion. Then when the direction but not the magnitude of the motion changes, the resolved part of the force in the direction of the motion becomes zero, and the force acting on the body is at right angles to the motion.

The Third Law of Motion is: "*To every action there is always an equal and contrary reaction; or the mutual actions of any two bodies are always equal and oppositely directed in the same straight line.*"

The primary meaning of this law is: "*With whatever force one body*

acts upon another, the second body will react upon the first with an equal force in the opposite direction." That the effect of the action and reaction appears at times to be quite incomparable is due to a disparity in the bodies acted upon and not in the forces themselves.

It follows that no force can exist alone, but must always be accompanied by one of the same magnitude, though opposite in sense, emanating from the body on which the first force acts. Therefore every force which acts between two members of a system has another force inseparably connected with it which counterbalances it when the motion of the whole system is taken into account; and the motion of the system, as a whole, is not affected by these internal forces or by any motion caused by them.

If another meaning be given to the word *action*, this law is capable of another interpretation.

After defining the velocity of a force or resistance to be the velocity of the point of application of the force resolved in the direction of the force, Newton makes the following statement: "If the Action of the agent be measured by its amount and its velocity conjointly, and if, similarly, the Reaction of the resistance be measured by the velocity of its several parts and their several amounts conjointly, whether these arise from friction, adhesion, weight, or acceleration—Action and Reaction in all combinations of machines will be equal and opposite." The *action of the agent* is the product of the force and the resolved part of the velocity of its point of application in the direction of the force—a product which is now called the rate at which the agent works, or the power of the agent.

Prof. Tait has translated Newton's statement into modern scientific language as follows: "Work done on any system of bodies (in Newton's statement, the parts of a machine) has its equivalent in work done against friction, molecular forces, or gravity, if there be no acceleration; but, if there be acceleration, part of the work is expended in overcoming the resistance to acceleration, and the additional kinetic energy developed is equivalent to the work so spent." It will be observed that this is a definition of the Law of the Conservation of Energy. Accordingly, Newton's second interpretation of the Third Law of Motion may be considered as an imperfect statement of the great principle of the Conservation of Energy.

If F_1 be the force which one body exerts on another, and F_2 the force which the second body exerts on the first, then according to the first interpretation of the third law

$$F_1 = -F_2$$
$$\text{or,} \quad F_1 + F_2 = O \qquad (4)$$

Equation (4) furnishes no relation between the four fundamental ideas of Dynamics.

The second interpretation of the law as enunciated by Prof. Tait may be expressed algebraically thus:

$$\Sigma(Ps) - \Sigma(Rs) = \Sigma(\tfrac{1}{2}mv^2) \qquad (5)$$

Where $\Sigma(Ps)$ is the sum of the products of each of the acting forces into the displacement of its point of application in its own direction; $\Sigma(Rs)$ a similar sum for resistances; $\Sigma(\frac{1}{2}mv^2)$ the sum of the kinetic energies developed.

If the system consists of only one rigid body, equation (5) reduces to

$$Ps - Rs = \tfrac{1}{2}mv^2 \qquad (6)$$

Writing F for the resultant of the acting and resisting forces, equation (6) becomes

$$Fs = \tfrac{1}{2}mv^2 \qquad (7)$$

Equation (7) is the familiar expression for the kinetic energy of a body starting from rest under a force F. Its first differential equation is

$$Fds = \tfrac{1}{2}d(mv^2) = mv\,dv. \qquad (8)$$

Hence $$F\frac{ds}{dt} = mv\frac{dv}{dt}$$

But $$\frac{ds}{dt} = v$$

$$\therefore F = m\frac{dv}{dt}$$

or, $$F\,dt = m\,dv \qquad (9)$$

From equation (8) *force* may be defined as the *ratio* which the change in the kinetic energy of a body bears to the distance through which the force acts. Thus force is a mere ratio analogous to velocity, and has not necessarily objective reality any more than velocity has. Speaking of force, Prof. Tait says: "What is really observed is either a transference or a tendency to transference of what is called energy from one portion of matter to another; whenever such a transference takes place, there is relative motion of the portions of matter concerned, and the so-called force in any direction is merely the *rate of transference*, or of transformation of energy per unit of length for displacement in that direction." It may be asked, "Why not consider energy a fundamental idea or concept instead of force?" Energy is generally conceded to have objective existence, and it possesses the important property of indestructibility or conservation, whilst force is generally conceded to be devoid of this property.

Force, *the ratio*, has been selected instead of energy, *the thing* whose ratio of transference force is, because it has been customary to begin with force and lead the student up to a consideration of energy. The idea of

force is more familiar to and more easily understood by a beginner than that of energy, and many of the propositions concerning force were well known long before the existence of energy was suspected.

It must be noted that transference of energy is *the cause* which alters a body's state of rest, or of uniform motion in a straight line, and that *force* is merely *the rate* at which this transference takes place. Hence the usual definition of force requires to be slightly modified.

Equation (9), which is derived from a particular case of the equation of energy, is the differential form of equation (1), which expresses the Second Law of Motion, and accordingly the Second Law of Motion may be deduced from the Law of the Conservation of Energy. It has been shown that the First Law is a special case of the Second, and that the Third is an imperfect expression of the Law of the Conservation of Energy; therefore Newton's Laws are not separate and distinct, but may all be included in and deduced from the Third, or its modern equivalent, the Conservation of Energy.

It is to be expected, then, that Newton's Laws, though three in number, will furnish only one independent relation between the four elements of Dynamics. The simplest form of this relation is given in equation (1). Any arbitrary values whatever may be assigned to any three of these quantities, and the corresponding value of the fourth determined from the most convenient form of the above relation. The object of Dynamics is to make this determination. Every problem in Dynamics is nothing more than a different form of the one general problem: *Having given three elements, to determine the fourth, or of the cognate one, to determine if certain given values of the four elements are consistent with the Laws of Motion.*

PATERSON, N.J., January 10th, 1891.

EARTHWORKS ON ROADS AND RAILROADS.

By C. H. Mitchell.

Mr. President and Gentlemen,—Earthworks are built for a certain purpose, and that purpose to sustain a load put on them in some manner. Like other structures, they are liable to injury or collapse, and it is necessary for the engineer to examine how best to prevent this. The greatest obstacles he has to surmount are presented by nature, but most frequently these can be avoided with a little care bestowed at the right time and place. Unless a good construction be followed by a good maintenance, the required end is seldom attained, so it is best to be careful in construction and the maintenance will not give much trouble.

With respect to the location of a piece of earthwork, there are a number of things to be remembered, and some of these might be briefly enumerated:

(1) Avoid cuttings or embankments in treacherous soil as much as possible, and especially if on a hillside.

(2) In exposed places in hilly districts find which side of the valley the snow remains longer, which receives more sunshine and wind, and which is better wooded.

(3) The destruction of an embankment may be caused by its obstructing natural watercourses of any kind.

(4) A road is safer on the side of a valley which is freer from watercourses.

Many other conditions might be mentioned, but space will not permit.

Proceeding next to the general considerations governing the construction of the slopes of cuttings or embankments, and determination of the permanent stability of any earth, it is always the *surface* of the embankment or cutting which will be first affected by the natural agencies. Experience has shown that different earths will repose safely at different inclinations, and on this basis an approximate set of tables of inclinations for earthworks of all kinds has been compiled. However, it will be apparent that these tables should not always serve as absolute guides in practice, for so much depends upon the accompanying circumstances and local peculiarities. By an inspection of the surrounding district, an approximate idea of the stability and peculiarities of the different earths occurring in the vicinity of the proposed work may be obtained. These

points, associated with the information derived from a set of tables, will usually enable one to arrive at a satisfactory arrangement of slopes. Just here a table of range of inclinations of several of the more frequently occurring earths may be inserted:

(1) Alluvial soil (loamy earth, clay, and 40 to 70% sand)	1½ to 1 to 2 to 1
(2) " " (clay loam, clay, and 30% sand)	
(3) Solid clay mixed with fine sand	2 to 1
(4) Solid blue clay, marl, etc.	1½ to 1 to 2 to 1
(5) Fine dry sand	
(6) Firm shale, surface protected	1 to 1
(7) Clean gravel	1½ to 1

Here it will be seen that the slopes most generally adapted for ordinary earths in cuttings and embankments range from 2 to 1 to 1 to 1.

In ordinary earths frictional resistance is the chief factor of stability. The amount of this resistance depends of course altogether upon the material and the conditions attending, as moisture, irregularity of character of soil, the process of excavation or deposition, etc. As for the moisture, it is found that the resistance is reduced by from 10 to 25 % for different materials when they are wet. Tables of frictional resistance for different earths have been prepared, by which means a slope can be partially determined. For ordinary earths, this co-efficient of friction ranges from 0.25 to 1.00. Consequently the slope of repose, say S to 1, is found by the expression $S = \frac{1}{F}$ where F is the co-efficient of friction. Hence in above cases

$$S = \frac{1}{0.25} \text{ to } \frac{1}{1} = 4 \text{ to } 1 \text{ to } 1 \text{ to } 1.$$

However, this is absolute, and does not make allowance for the above-mentioned conditions of irregularity in the material and construction. If it were possible to build a piece of earthwork in which the material would always remain as originally built, the slopes could be mathematically determined, knowing the co-efficients of friction and cohesion. But in determining the inclination, it is not so much the angle at which the artificial surface will stand, at, or a short time after being built, for this is not the object; but the question to be answered is, "What will be the approximate position which will permanently remain so as to prevent movement?" This chiefly depends upon the material, exposure to weather, water, vibration, and the height or depth, as the case may be. In all earth where the cohesion is small a straight slope is the best, for it has an even surface, which prevents the accumulation of water, and it also offers the least surface to the weather; but in material where the cohesion is considerable, the slope, as a rule, which is naturally assumed is curved. This conclusion was originally arrived at by an investigation of the laws of pressure in

connection with the theoretically correct slope, and has since been corroborated by experiment; for it has been found that in high embankments especially the slope assumes a considerable curve after it has been allowed to weather and settle. If you notice a slip in an embankment of earth, you will in all probability find that the upper portion of the new or exposed surface is concave, whilst the lower portion is slightly convex, being caused by the upper portion falling, and the lower part, while receiving it, being pressed outward. This principle is very frequently followed in high embankments of treacherous soil, making, for an example, the following slopes for an embankment 60 feet high and of formation width 24 feet:

Upper 20 feet	at a slope of	1½	to	1
Middle 20 feet	" " "	2	to	1
Lower 20 feet	" " "	3	to	1

The next point is that of the approximate safe maximum height or depth of embankments or cuttings, and in connection with this the approximate safe maximum load upon different earths, considered as either natural ground (for foundation) or deposited earth as it occurs in embankments.

First, the safe maximum compressive load on natural ground for the purposes of foundations. Tables have been compiled for the approximate safe maximum load in tons per square foot for different earths upon which earthworks are generally built. The following is copied from a set of these tables, showing the compressive strength of the different foundations:

(1) Bog, morass, marshland, etc.	0 to 0.20	tons	per	square foot.
(2) Alluvial earth, loam and loamy earths	0.35 to 1.50	"	"	"
(3) Damp clay	1.50 to 2.00	"	"	"
(4) Intermixed beds of different sound clays	3.00	"	"	"
(5) Solid clay mixed with fine sand	4.00	"	"	"
(6) Solid blue clay, marl, boulder gravel, etc.	5.00 to 8.00	"	"	"
(7) Ordinary superficial sand beds	2.50 to 4.00	"	"	"
(8) Compact gravel	7.00 to 9.00	"	"	"

In foundations, etc., *rock* is not usually loaded with a greater weight than from 8 to 20 tons per square foot. Reference to authorities on the resistance of rocks to different stresses will give the safe load per square foot, but even upon rock in its natural location this should not exceed one-tenth of the maximum tabulated load.

In the construction of cuttings there is scarcely any limit to the depth, except a due regard to economy, as long as the slopes are sufficiently flat and drainage is properly effected. It is generally found in a long cutting, when it is deeper than 60 feet, that it is cheaper to tunnel, *i.e.*, in the case of ordinary soil. For embankments, however, the load upon the ground and the deposited material restricts the height in a degree, or, on the other

hand, necessitates the base being gradually spread out. Hence the consideration of the height of the embankment resolves into two separate problems, viz., the limit to which the embankment may be deposited; and, secondly, the safe load that the earth of which the embankment is composed will sustain. For the solution of the first of these, we have the following:

$$H = \frac{S}{W}$$

where S = Safe load in tons per square foot upon *natural* ground.
H = The theoretical limiting height in feet of embankment.
W = Weight in tons per cubic foot of deposited earth.
S and W being found in tables.

For the solution of the latter part of the problem, it is well to remember that:

Excavated earth cannot be restored in bulk to its original condition. Loam and light earth shrink as much as 12%, while gravel and sand are less.

Earth is usually, soon after deposition, subject to vibration and weather.

Therefore, taking these and other points into consideration, the question is, what deduction is to be made from the tabulated maximum safe load for an unexcavated earth, and to ascertain the safe sustaining power of the *same earth when deposited?* Much depends upon the conditions of the earth and its peculiarities; and for this reason the earths are divided into two classes, viz.: (1) Granular, such as sand, clean gravel, etc., or such as are insoluble in water; and (2) non-granular. A table of approximate safe heights for embankments under these two heads, compiled from different authorities, is given below:

		feet.	
Granular Earths	Clean gravel	90	Approximate safe
	Sharp compact sand	80	permanent height.
	Ordinary loamy sand	40 to 60	Good conditions.
Non-granular Earths.	Alluvial soil from river bed	5 to 8	
	Ordinary alluvial soil	15 to 30	
	Boulder clay	25 to 30	
	Damp clay soil	25 to 30	

In cuttings the depth might safely be increased by 25% over the above. It is seldom economical to make an embankment more than 70 or 80 feet high except for short lengths where the foundations for a bridge are known to be of a treacherous character, or where there are deep cuttings adjacent which cannot be avoided, for then it becomes a question of carefully constructing the embankment merely as an immense spoil bank.

We will now consider the different systems of deposition of an embankment and the circumstances in connection with it. One of the chief objects in the deposition of an embankment is to make it homogeneous, and prevent, as much as possible, different kinds of earth being tipped in different states of weather. Careless and intermittent tipping conducted in wet and dry weather, and with several qualities of earth, is a frequent source of slips or subsidences later on. It may appear very easy to decree, from slight acquaintance with the location of any piece of work, arbitrary rules as to the quality of material, manner of handling, and so on ; but the exigencies of such, upon the carrying out of the plan, may demand the very opposite procedure. For instance, it may happen that there is no available material for miles about, except, say, sandy clay, with which we require to build an embankment of considerable height. This, under ordinary circumstances, would not be thought of, but it has sometimes to be done, and *will* have to be done. Care should be taken that the earth deposited be, throughout the embankment, the same or nearly the same ; and when in a cutting from which is being taken material for an embankment a seam of unstable soil occurs, it should not be tipped into the embankment, but run into a spoil bank. It often happens that it is cheaper to obtain earth for small embankments from what are called side-cuttings (forming a sort of borrow pit) rather than from regular cuttings, especially if land be plentiful. These side-cuttings are cuttings parallel to the foot of the slope a short distance from it, and thus in this way they form a good drainage system. However, this will be mentioned further on. Another point to be observed in deposition is that the material be as much as possible in particles of uniform size, thereby increasing cohesion.

The first operation for the deposition of an embankment is the preparation of the ground on which it is to rest. Solid mounds or hillocks, etc., must be left, but vegetable or brush growth should be removed. In particular cases, it is well to plough the ground in places to offer a rough surface, and this especially for embankments on slightly sidelong or hillside ground. In steeper sidelong ground, however, it is better to trench or cut the surface into steps, as it were, and by this means offer a rough foundation to prevent movement, as well as a system of partial drains.

We now come to the drainage of the natural ground on which the embankment is to rest, so that the water percolating through the embankment may be drawn off. This may be accomplished by a system of parallel rough stone drains running transverse to the embankment at a distance of, say, 18 feet apart, with several longitudinal drains the entire length of the embankment.

One frequent cause of subsidences in embankments after being com-

pleted is the deposition of material in all states of humidity, from dry and dusty soil to wet and saturated soil. This has a tendency to induce stratification, as it were, in the work, and consequently an unequal settlement. All saturated earth taken from a cutting should, if practicable, be run to spoil. However, this is not always possible, for it may appear in small patches, and it would not pay to shovel it into wagons for the purpose. But if it occurs in considerable quantity, the above rule should be followed. No mould, mud, soft pasty earth, frozen earth or snow, should, under the best construction, be put into an embankment.

We now come to a most important part of the subject, viz., the system of tipping. Most embankments (take, for instance, railroad embankments) are formed in masses of not more than, say, 3 cubic yards at most, according to the capacity of the wagons. From this we see that however short may be the "lead" (*i.e.*, the distance from the excavation to the embankment), this 3 cubic yards of earth will be greatly disturbed, both by the jolting movement of the conveyance, and chiefly by the act of tipping down the embankment head. The greater the height of the embankment, the greater will be this effect. No solid lumps of considerable size should be allowed to be tipped with shovelled material of the same kind, for then these lumps will roll down the slope, perhaps lodging on the way, and forming (when in large numbers) a mass which is not strictly homogeneous, and hence not in accordance with good construction. The lumps can be easily broken up. In the case of granular earths, as sand and gravel, the height of the tip would not need so much attention, as the particles would fall into repose equally, and would not be affected much by water. It is generally found that it is best to erect the embankment to the full formation width, because it may be that the earth afterwards applied would differ in character from that originally deposited; also the original would have weathered for a certain length of time, and the new material would not be stable. If in wide embankments there should be a number of tipping heads or roads; they should proceed equally, in order that the material be the same, and equally exposed. In wet weather, or when the soil is treacherous (as clay, for instance), it is found better to diminish the height from which the material is tipped, and build the embankment in several layers or courses, depositing each layer to its respective necessary width, care being taken that the lower layer is sufficiently wide to receive the top layer; the top of the lower layer should be made slightly concave.

It often happens that slips occur when the central portion of an embankment is built of one material and the slopes of a different, the latter slipping or sliding on the former. No side tipping should be allowed in a new embankment, and, if possible, additions to the slope should not be

made, although it may be necessary in trimming up the slope, but this should be done by the bank-head men as the earth is deposited, when the slope should be made as even as possible to prevent lodgment of water, etc.

The most critical and tedious part of the construction of an embankment is the closing up of the earthwork and making a firm joint between the surfaces which are to be closed, wherever they may be. In small embankments the tipping is usually done from one end, and thus the work is built, the junction being made on the opposite side and with the natural surface, which should be prepared to receive the deposited earth in the same way as for foundations for the embankment. However, the question of tipping from one or both sides depends altogether upon the cutting or place where the material is being obtained. In large embankments it is preferable to tip from both sides and close at the centre, as the joint can be made more homogeneous than at the end. It is necessary therefore that the earth between the two tip heads be of the same character and condition as nearly as possible. It will generally be found that it will require more material to close two high tip heads than would appear from the computation of the earthwork.

We will now turn our attention to the drainage of earthwork. In the first place, to consider the systems of draining the *beds* of the different works, viz.:

(1) Cuttings. The bed of the cutting is of course composed of the natural ground, and other than side ditches at the foot of the side slopes requires no special drainage except that necessarily imposed by the highway proper. These side drains are built quite large, to receive all the water from the slopes and conduct it beyond the cutting. They should be at least two feet wide and one foot deep, and should be built without sharp bends, by which the slope, etc., are eroded. In good firm soils it is hardly necessary to stone these ditches, but in sandy and loose soils it is, for the wash of the water will erode the slope and carry away considerable silt. To prevent this, the ditches can be filled with broken stone, or, better still, covered or pipe drains can be substituted.

(2) Embankments. This has been slightly mentioned before. At the base of the slope a deep ditch might be cut as near the fence as convenient. For ordinary soils this is sufficient; but where the earth retains moisture easily, it becomes necessary to drain the seat of the embankment. One way is to construct (before depositing any material) trenches at intervals, at right angles or obliquely to the centre line, filled with stone or gravel. A cheaper method is to excavate the foundation so that the centre is several feet below the sides, a small trench provided with suitable inclinations, and

filled with broken stone, etc., running along the centre line to the nearest culvert.

In regard to culverts, they are usually placed at the deepest portion of an embankment to conduct the stream (if any) beneath. They should be large enough to admit a man, and are usually, of a considerable size, and built of masonry in the form of an arch, or heavy timbers. In the former, it is well to have a coat of cement on the inside to aid the quick passage of the water, and in all culverts this same idea should be followed, so as to reduce the friction as much as possible. Smaller culverts may be built of brick, concrete, or rubble concrete, preferably in the form of an arch. Culverts should have provision at the ends, especially the upper end, to guard against the wash of the stream. This is a most important point, for if the toe of the embankment be exposed to the current, it is apt to be disturbed by undermining, etc. This is best prevented by building splay wing walls, by which the water is kept from the toe of the slope and guided into the culvert. Besides this, it is good practice to build masonry retaining walls at the base of the slope in the vicinity of the stream, to guard against the results of the stream "backing up" at flood time; this, however, should be seen to when building the culvert itself that it should be large enough to accommodate all the water which could come down.

We will now consider the drainage and protection of the slopes of earthworks. There are many ways of doing this. With respect to cuttings, the chief consideration is "to gently extract and conduct the water so as to avoid any accumulation on or beneath the original surface which would affect the slopes." The main point in either a cutting or embankment is to keep it in a uniform state, so as to facilitate equal settlement. This is best effected by preventing any water from collecting in depressions in the slopes; for, as water is the chief cause of slips, it must not be allowed to accumulate in such a way as to saturate to excess any particular portion of the slope, and thus make a slip possible. One frequent cause of this accumulation arises from the position of the strata outcropping in the slopes of a cutting. Wherever a permeable stratum overlies an impermeable in a section of tilted or inclined strata, an increased flow of water may be expected. In soils of a sandy or loamy nature percolation of water must be provided for, for there will be a large quantity of the percolated rainfall in the surrounding land, which will manifest itself on the slopes of the cutting. In clay soils this percolated water usually appears in fissures and crevices, whilst in soils of a mixed nature springs are the most troublesome. In cuttings, the surface water from above must be drained as much as possible away from the slope. This is done by building catchwater

drains at the top of the slope before the excavation of the cut is commenced. These drains should be made as impermeable as possible; for if they are permeable, it must be remembered that they are agents in localizing the flow of the water, and it would perhaps be better if they were omitted altogether. These catchwater drains, if built, should be near the fence, have a considerable inclination, and should be connected with the regular surface drains down the face of the slope. All field drains, etc., should be conducted into these catchwater drains. A spoil bank should never be deposited near the top of a slope of a cut, since it imposes an extra weight and localizes water. The slopes proper can be drained by wells, closed or open channels, pipes, tile drains, or catchwaters. To describe minutely each of these is not in place here, but in a general way their necessity for different purposes may be regarded. Rock and solid impermeable earth may require only to be surface drained, which may be easily done by open channels down the slope, either directly or at an inclination. But in all treacherous material, such as sandy loam, clayey soils, and mixed soils, deep draining is necessary. In sandy and mixed earths, extra precautions, besides the usual side drains, and top drains, may be to sink, on the slope, wells filled with broken stone, etc., having drains leading from them. Tile drains might also be used. In clay soils, especially in embankments, deep draining is necessary, and the drains, which need not be large, might be made of rubble stone. In embankments, the drains should be built as the material is deposited, and should be at short intervals throughout the mass, and emptying into the surface drains of the slope. It is a question whether the drains on the slopes should be perpendicular to the side drains or inclined to them. If the soil is likely to slide, or is treacherous, it is perhaps better to have them run directly down, because otherwise the cohesion will be destroyed. It is generally found that "filled in" trenches are successful, and they are certainly cheaper. They may be made of stone, set in gravel, ashes, or such material, and should be at least 3 feet wide and 1½ feet deep and should have careful and deep connection with the side drains at the foot of the slope. It does not always follow that the more of these drains there are on a slope the better will be the drainage, for a large number of them may tend to weaken the slope.

The toe of a slope is its weakest point, and should be protected in preference to everything else. There are several ways of doing this. First, and simplest, for embankments only, cut a trench of considerable size in the natural surface, and so placed as to allow the slope of the deposited material to abut against it. Second, an impervious retaining wall, say, of masonry, with a pervious backing of gravel or sand, may be

built, allowing the slope to abut against it. This masonry retaining wall should have a deep foundation, and be of such dimensions as will be required by the weight imposed and the inclination. At intervals of at least every ten or twelve feet a channel through the base of the wall should be left, so as to allow the water which comes down through the porous backing to find its way to the side drains. These channels, called "weep-holes," need not be large. The height of the retaining wall will of course be governed by existing circumstances, but in most cases need not be more than, say, five feet. One trouble with these walls in our country is that, on account of being constantly exposed to moisture, frost will cause them to bulge out and weaken the slope. The only way to prevent it seems to be to secure thorough and rapid drainage, and shore the wall with timber. These walls are found most useful in loose soil, such as sand, or gravelly sand, but in cohesive soil, as clay, etc., they are hardly necessary if good slope protection and drainage is maintained.

Third system of protecting toe: Build a pervious wall or "counterfort" of gravel, rubble, or other firm material. This is found useful in loamy earth, or soil of a semi-cohesive nature, and even clay. The gravel, etc., should be well rammed in shallow layers, and the whole should have a foundation considerably beneath the base of the formation. A good example of well-drained cuttings is found on the G.T.R. where it passes beneath the Welland Canal. There are several miles of cuttings having inclined stone drains running diagonally across the slopes, heavy stone retaining walls, etc., etc.

As to the protection of a slope, the most common method is by vegetation. This vegetation should be compact, uniform, and remain throughout the year. Grass sown on the incline is found to be the best for this, for its roots bind the earth so well together. The less cohesive the soil is, the deeper the roots should be; but for clay soils the roots need not be so deep as close together to prevent water furrowing the slope. There are some soils, however, on which it is impossible to get grass or other such vegetation to grow. Of these, sand is the most troublesome. It is found very frequently in moist sand that willows will grow well, and these with their large roots are very useful. It has been found that quite often slips are prevented by planting low saplings or shrubs on a slope; but care should be taken that the roots do not strain the ground by force of wind or other cause

In our country, snow is a frequent cause of trouble in cuttings and hill-sides. Many preventive measures have been adopted, of which some might be mentioned:

(1) Building snow sheds.

(2) Building permanent or portable screens.

(3) Increasing the width of formation.

First; snow sheds are of course expensive, but are the most effectual. They are used on the C.P.R. and the Intercolonial to a great extent. They must necessarily be built very strongly to resist snow and ice slides.

Second; screens, such as earth mounds, hedges, fences, etc., are effective, and comparatively economical. Close trees, such as pine, spruce, or cedar, planted some distance back of the cess or crown of the slope catch the snow considerably, but lessen the effect of the wind on the slopes for drying purposes in the wet season. A trench should be built on the lee side of the trees to carry away the snow water.

Third, the increase of the formation or roadway is also effective, as it gives more surface and allows more room for the snow plough and the section men to work. In such places the side drains should be very deep.

THE COMPUTATION OF EARTHWORK AND OVERHAUL BY MEANS OF DIAGRAMS.

By Edward F. Ball.

Mr. President and Gentlemen,—I greatly regret that this paper will not partake of that "practical" nature descriptive of constructive details which is so keenly appreciated by engineers. Although not "practical" in the usually accepted meaning of the term, the subject will be found of great practical utility to those who have occasion to make extensive computations of earthwork and overhaul, especially on railway work.

The first part of this paper, that relating to earthwork, is extracted from that admirable book entitled "Computation from Diagrams of Railway Earthwork," by A. M. Wellington. My excuse for occupying your time with a subject treated exhaustively in the work referred to is that this book is of comparatively recent publication (1888), and is not nearly so widely known as it deserves to be.

The method described in the second part of this paper relating to overhaul is believed to be different from anything published on the subject, and combines the two desirable features of accuracy and readiness of application. The invention of this method is claimed by a Dutch engineer on the Lehigh Valley Railway, from whom the writer obtained a description delivered in a language in which every "w" was converted into a "v"; "th" into "d"; "yes" into "yah," or more frequently "yap," etc.; but as language was given to man to *conceal* his thoughts, why attempt to criticise the shell that envelops and hides the kernel?

The writer wishes to put in a small claim for distinction for modifying the method of calculation so as to secure the greatest possible accuracy, but is not entitled to any further credit.

COMPUTATION OF EARTHWORK.

The old method of computing solidities by means of end areas is very laborious, and unless the cross-sections are taken frequently enough to ensure only a small difference between two consecutive end areas is widely erroneous, the error being in favor of the contractor, *i.e.*, the calculated volumes being in excess of the actual volumes. The application of the prismoidal formula in this method is so lengthy and tedious as to be entirely out of the question.

The usual method of calculating the areas of "three-level" section is as follows:

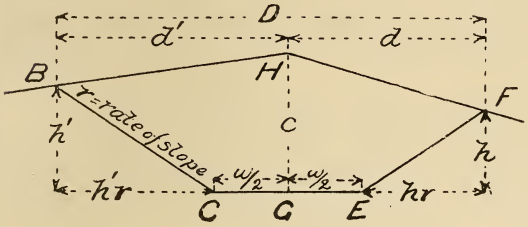


FIG. 1.

2 area of $\Delta\ BCG = \frac{w}{2} \times h'$

2 " " " $FEG = \frac{w}{2} \times b$

2 " " " $BHG = cd'$

2 " " " $FHG = cd$

$\therefore$ 2 area of whole section $= c\,(d+d') + \frac{w}{2}\,(h+h')$

or, $$A = \frac{c\,(d+d') + \frac{w}{2}\,(h+h')}{2} \qquad \text{Eq. (1)}$$

This equation contains four variables, A, c, $(d+d')$ and $(h+h')$, but d and h are functions of each other, for d is always equal to $hr+\frac{w}{2}$, and $h = \frac{d-\frac{w}{2}}{r}$

Substituting this value of h in Eq. (1),

$$A = \frac{(d+d')}{2}\ c + \frac{\left(\frac{d-\frac{w}{2}}{r} + \frac{d'-\frac{w}{2}}{r}\right)}{4}\ w, \text{ which simplifies to}$$

$$A = (d+d')\frac{c}{2} + (d+d')\frac{w}{4r} - \frac{w^2}{4r} \quad \text{or letting } (d+d') = D$$

$$A = \left(\frac{c}{2} + \frac{w}{4r}\right) D - \frac{w^2}{4r} \qquad \text{Eq. (2)}$$

In the foregoing equations the lineal dimensions are always expressed in feet, but the solidity S is required in cubic yards.

Letting S = the end-area solidity of a solid of the usual length, 100 feet,

$$S = \frac{A+A'}{2} \times \frac{100}{27} = (A+A')\frac{100}{54}$$

In the formula

$$S = (A+A') \times \frac{100}{54} \text{ or } S = (A+A') \times \frac{50}{27}$$

it is of course apparent that

$$S = \left(A \times \frac{50}{27}\right) + \left(A' \times \frac{50}{27}\right)$$

or, to express these figures in words, the total end-area solidity of a prism

100 feet long with end-areas A and A' = the solidity of a prism 50 feet long of end-area A plus the solidity of a prism 50 feet long of end-area A'.

Let $s = A \times \frac{100}{54}$, or the solidity of a prism of end-area A and length 50 feet:

$$\therefore \quad s = \left\{\left(\frac{c}{2} + \frac{w}{4r}\right) D - \frac{w^2}{4r}\right\} \times \frac{100}{54} = \frac{50}{54}\left(c + \frac{w}{2r}\right) D - \frac{25w^2}{54r}$$

In this equation there are but three variables: c the centre height, D the width between slope stakes, and s the corresponding solidity in cubic yards for a length of 50 feet. If we construct diagrams for values of c, taking ordinates parallel with the axis of x to represent values of D, and ordinates parallel with the axis of y to represent values of s, we will have a number of radial lines as shown in plate 1.

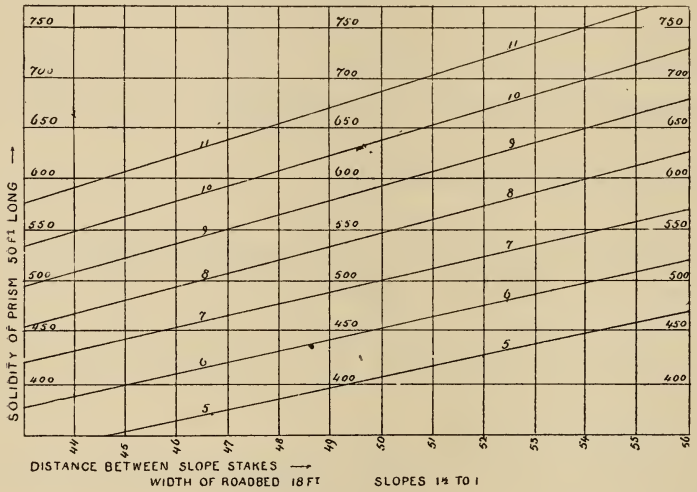


PLATE I

Suppose, now, that we wish to find the solidity of a railway cut 100 feet long, width of roadbed 18 feet, slopes 1½ to 1 foot, distance between slope stakes 48 and 50 feet, depth of centre cuts 10 and 11 feet respectively. Follow up the vertical line corresponding to 48 (plate 1) to the intersection of the diagonal line corresponding to 10; the horizontal line at the intersection represents 611 cubic yards. Similarly with the other section, the solidity is 687 cubic yards. The sum of these = 1298 cubic yards. Should the length of the cut be 30 feet instead of 100, multiply the result by 0.3 = 389 cubic yards.

The diagram shown in plate 1 is not drawn very accurately, so that the results obtained from it do not quite agree with the above.

Accompanying Mr. Wellington's book are diagrams for different widths

of roadbed and slopes, and also a number of others for various uses. By the use of these the tedious labor of computing areas, which, by the method shown in Eq. (2) is more than one-half the total work of computation, is entirely avoided. In some other methods the saving is from two-thirds to four-fifths.

Some engineers will work out solidities to the decimal part of a yard, but this is ridiculous nonsense, for no cross sectioning is done so accurately as that. At first sight, it would appear that the locus of c in the equation

$$s = \frac{50}{54}\left(c + \frac{w}{2r}\right) D - \frac{25w^2}{54r}$$

would be a curve, but, in reality, it is a straight line, for the expression $\frac{25w^2}{54r}$ is constant for any one diagram, and the equation may be written $s = \frac{50}{54}\left(c + \frac{w}{2r}\right) D - c''$, which is of the first degree and represents a straight line.

Having examined a very rapid and accurate method for computing end-area solidities, let us investigate one for determining them precisely by means of the prismoidal formula, which is

$$S = \frac{A + A' + 4M}{6} l$$

in which A and A' are the two end areas, M the area of a section midway between (which is *not* the mean of A and A'), and l the length of the solid. We cannot reduce this to a simple formula with three variables as in the previous case, but we can obtain a ready method for finding the correction to be subtracted from the result obtained by the end-area method. Without going through the various deductions, I will simply state that diagrams are constructed from which the correction may be found having given the differences $c - c'$ and $D - D'$, in which c and c' are the centre heights at the ends of the solids, and D and D' the corresponding distances between slope stakes.

OVERHAUL.

Let us suppose that the limit of free haul is 1000 feet, and the prices for overhaul are 1 cent per cubic yard per 100 feet up to 2000 feet, and ½ cent per cubic yard per 100 feet beyond 2000 feet. It first becomes necessary to find the points at which overhaul begins, *i.e.*, how far beyond the grade point the material from the cut would build the embankment without exceeding the limit of free haul—1000 feet, and also the limit of the 1 cent rate where the haul reaches 2000 feet, after which we find the average distance that the material was hauled in the 1 cent rate and also in the ½ cent rate. This presents the appearance of a very easy problem, but its *accurate* solution requires considerable care.

Commencing at the grade point *G* (see profile), add up the total number of cubic yards of excavation and embankment to each station as follows :

EXCAVATION.

From grade point to station	2385 =	100 cubic yards.
" " " "	2384 =	330 " "
" " " "	2383 =	1330 " "
	etc., etc.	etc., etc.

EMBANKMENT.

From grade point to station	2386 =	70 cubic yards.
" " " "	2387 =	870 " "
" " " "	2388 =	2570 " "
	etc., etc.	etc., etc.

These results should be tabulated in the following form :

EXCAVATION. +			EMBANKMENT. −		
Station.	Quantity C. Y.	Total Quantity from G C. Y.	Station.	Quantity C. Y.	Total Quantity from G C. Y.
"G"			"G"		
	+ 100			− 70	
2385		+ 100	2386		− 70
	330			800	
84		330	87		870
	1000			1700	
83		1330	88		2570
	1810			3000	
82		3140	89		5570
	2800			3500	
81		5940	2390		9070
	3670			4000	
2280		9610	91		13070
	4300			4300	
79		13910	92		17370
	4300			4000	
78		18210	93		21370
	4630			4000	
77		22840	94		25370
	4300			3300	
76		27140	95		28670
	3970			2500	
75		31110	96		31170
	3360			1700	
74		34470	97		32870
	1810			800	
73		36280	98		33670
	820			200	
72		37100	99		33870
	80			− 80	
71		37180	2400		33950
				+230	
2370			1		33720
				500	
			2		33220
				100	
			3		33120
				+100	
			4		33020
				− 200	
			5		33220
				450	
			6		33670
				780	
			7		34450
				1100	
			8		35550
				1460	
			9		37010
			2410		

Now take a sheet of cross-section paper and from the preceding table plot curves representing volumes for excavation and embankment, as shown in plate II; distances along *ox* representing lineal feet and along *oy*, cubic yards. The vertical lines are numbered from 2370 to 2410 to correspond with the chainage, as shown on the profile. Wherever a point is established on either curve make a small circle, and draw a horizontal line across to the other curve. Scale the length of this line and note the result, as shown in plate II. From station 2400 to 2404 a small cut will be noticed, but this is treated as a negative fill, and in adding up the volumes in embankments this is subtracted and causes the curve to drop at *AB*, plate II.

Now take a scale, and, keeping it always parallel with the axis of *x*, find at what points the two curves are 1000 and 2000 feet apart. Thus it is ascertained that the limit of free haul is at station 2390 + 10, and the limit of the 1 cent rate at station 2395 + 30.

Let us compare the hauling of a cubic yard of earth 1 foot horizontally to the raising of a pound weight 1 foot vertically. This is called a foot pound of work, and we may coin a similar expression, a "foot yard" of work, which means the work done in hauling a cubic yard of earth a horizontal distance of 1 foot. Suppose, now, we have a very small cut of, say, 12 cubic yards, and that the first 2 yards were hauled 10 feet, the second 2 yards 11 feet, the third 2 yards 12 feet, etc., and the last 2 yards 15 feet. The total amount of work done:

2	× 10	=	20	foot yards.
2	× 11	=	22	" "
2	× 12	=	24	" "
2	× 13	=	26	" "
2	× 14	=	28	" "
2	× 15	=	30	" "
			150	foot yards.

We may simplify the above computation by dividing the 12 cubic yards into 2 groups of 6, instead of 6 groups of 2, thus:

6	× 11	=	66	foot yards.
6	× 14	=	84	" "
			150	foot yards.

Thus in actual work we may divide the total volume into smaller ones of such a size that we can determine very closely the average haul for each yard in that particular volume. By consulting the diagram, plate II, we find that from 9510 to 13070 cubic yards the average haul is $\frac{1000 + 1190}{2}$ = 1095 feet; therefore the amount of work done = (13070 − 9510 cubic

yards) × 1095 feet = 3560 × 1095 = 3898200 foot yards. Similarly, between 13070 and 13910 the amount of work done = 840 × $\frac{1230+1190}{2}$ = 840 × 1210 = 1016400 foot yards, and so on up to the 2000-foot haul. By working out all these multiplications as in the table, we find that the total amount of work done in the 1 cent rate = 29928250 foot yards. Now the total number of cubic yards moved between the 1000 and 2000-foot limit = 29600 − 9510 = 20090 cubic yards, and the total amount of work done, or, in other words, the product of the number of yards multiplied by the distance hauled = 29928250; therefore the *average haul* is obtained by dividing this product by the number of cubic yards = $\frac{29928200}{20090}$ = 1490 feet, which is the desired information.

HALF CENT RATE.	VOLS.	DIST.	PRODUCT.
	730	3623	2644790
	730	3505	2558650
	1080	3380	3650400
	970	3215	3118550
	630	2300	1449000
	1760	2177	3831520
	1510	2053	3100030
	7410		20352940

ONE CENT RATE.	VOLS.	DIST.	PRODUCT.
	930	1968	1830240
	1530	1892	2894760
	1770	1803	3191310
	2530	1697	4293410
	1470	1603	2356410
	3160	1497	4730520
	840	1410	1184400
	3460	1310	4532600
	840	1210	1016400
	3560	1095	3898200
	20090		29928250

Now, by looking at the table, it will be seen that the sum of all the products really represents the area between the two curves and the 1000-foot and 2000-foot line of haul. This may be obtained much more readily and with sufficient accuracy by drawing heavy lines containing an equal area, as shown on diagram, and computing the area of the enclosed figure. By this method the average haul is found to be 1491.5 feet, a difference of only 1½ feet. This is the great advantage of this particular method of computing overhaul; for after the diagram is plotted and the heavy lines drawn, the computation is very simple and quite accurate. Should the utmost precision be demanded, the method before described will give it.

In the example given, the average haul in the 1 cent rate is found to be 1490 feet, and in the ½ cent rate 2747 feet. It must not be understood that the contractor is paid 1 cent per yard per 100 feet for 20090 cubic yards hauled 1490 feet, as the first 1000 feet is free haul. The amount due on the 1 cent rate would therefore be 20090 cubic yards × $4\frac{9}{10}$ cents = $983.78. Similarly, the ½ rate amounts to

7410 cubic yards hauled 1000 feet @ 10 cents per cubic yard.

7410 cubic yards hauled 747 feet @ ½ ($7\frac{47}{100}$) cents,

= 7410 cubic yards × 10.3735 cents = $1017.76

WATERWORKS SYSTEMS OF AMHERSTBURG AND ESSEX.

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By A. T. Laing.

Gentlemen,—It was the lot of the writer to be engaged as assistant engineer on the above work. In view, therefore, of the fact, I concluded to lay before you the methods by which the work was conducted, and to relate a few facts, which, I hope, may prove interesting and instructive to you.

The great number of advantages to be derived from an efficient system of waterworks is too well known to you to necessitate my occupying space with that part of the subject. Our engineering journals contain a great deal of useful information on waterworks; but as most of the matter pertaining to this subject deals very largely with the theory and the construction of extensive systems, I shall therefore confine my remarks to the practical part of the subject, and its application to such systems as we have before us.

When a corporation contemplates establishing a system of waterworks, it is their first duty to consider both quality and quantity of water supply, and the financial condition of the town. If the project be deemed at all practicable, an engineer is engaged to investigate the matter and give an estimate of the probable cost. The council then submits a by-law for this amount for the approval of the ratepayers, by the passing of which they are warranted in proceeding with the work. A competent man is engaged as consulting engineer, whose duty it is to prepare all plans and specifications necessary for the construction of the work, and to inspect it during erection. Tenders are then advertised for, and the work may be let either in bulk or in sections, as may be deemed most advisable.

Amherstburg is a small town very beautifully situated on the watery highway of Canadian and American commerce, viz., the mouth of the Detroit River. It was named after General Amherst, and was the scene of several engagements during the war of 1812, in commemoration of which event the old fort and blockhouses still stand. It has also been alleged that it was at this place that the old hero, "Uncle Tom," first entered "the land of the free."

The agitation for waterworks began in the fall of 1890. Early in 1891 the by-law was passed, upon which Mr. John Galt, C.E., Toronto, was

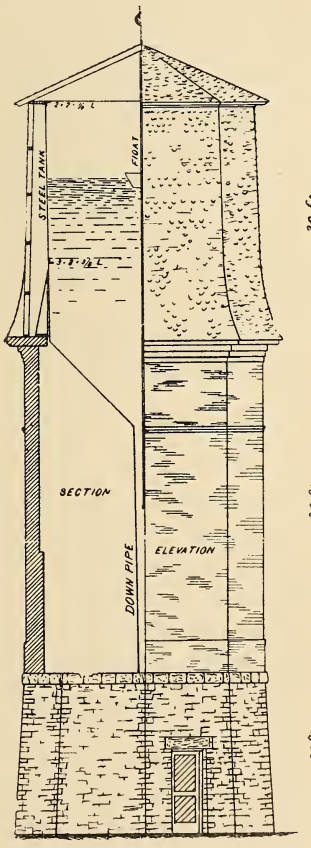
engaged as consulting engineer. The plans were prepared at once, and operations were commenced about the 1st of May, 1891.

With a town so situated, no trouble could arise from water supply. Near the river a vertical shaft was sunk, 10 feet in diameter, 15 feet deep, lined with brick laid in cement. Into this the water is conducted by gravity through a 12-inch conduit pipe, extending 200 feet into the river. In order that this pipe may adjust itself to any unevenness in the bed of the river, it is made with the usual ball and socket flexible joint. Joints of this kind are made on the same principle as the joint for a compass-box on the head of a jacob-staff. The bell is bored out, leaving a smooth concave surface inside. The spigot which enters this is provided with a notch, which serves to hold the lead in place, thus making a close joint which may safely move through an angle of 30 or 40 degrees without breaking or leaking. This greatly facilitates the operation of laying the pipe under water; for each joint may be made above water and the pipe lowered afterwards. This part of the work was conducted in the following manner: A scow was brought close to the bank and loaded with pipes, and as each joint was made it was moved out one length, letting the pipe lower like a chain from the rear into the river. This is all that is required with this part of the work, and, if properly understood, it may be conducted more rapidly than laying pipes in the streets.

The intake for this conduit consists of a 12-inch right-angled bend. The open end is protected with a sieve, and the other end, which is connected with the conduit, is provided with a broad casting, which retains the pipe in an upright position, thus allowing the water to enter at a point about five feet above the bed of the river, and preventing the entrance of sediment. At the end next to the well is placed a gate valve, which may be closed when the well requires cleaning. This pipe is produced downwards to within a few feet of the bottom, so as to act as a syphon, when the portion of the pipe between the well and the river is above the varying water level, and from this well the water is drawn by the pumps through a 10-inch suction pipe.

The pumps are of the compound duplex direct-acting type, having capacity for raising water about 20 feet and delivering at a reliable fire-speed about 800 gallons per minute against a hydraulic pressure of 100 lbs. per square inch, with a steam pressure of 80 lbs. per square inch. The steam for this purpose is furnished by an ordinary boiler, which is fed by a duplex feed-pump. This pump forces the water through a heater, through which the exhaust steam from the large pump passes, thus feeding the boiler with water at a high temperature and saving fuel. The pump and boiler house is built in connection with a very commodious seven-room brick dwelling for the convenience of the man in charge.

From the pumps the water is forced into the system through a 10-inch main, which also is provided with a valve, so that the pressure of the system may be shut off the pumps at any time. Connected with this main, and about 100 feet from the pumping station, stands an elevated storage tank. This tank, which was designed by the engineer, is 16 feet in diameter and 20 feet deep, and is made of steel riveted together in five courses each four feet high. The lower course is $\frac{5}{16}$ inches thick, the next two $\frac{1}{4}$ inches, and the remaining two $\frac{3}{16}$ and $\frac{1}{8}$ inches respectively. This work is stayed with two angle bars riveted all around inside, one at the top 2x2x$\frac{1}{4}$ inches and the other 3x3x$\frac{5}{16}$ inches midway down, as shown in the accompanying cut. The bottom also is of steel $\frac{5}{16}$ inches thick, and is an inverted cone 8 feet deep. The object for making the bottom this shape is to diminish the entry head, thus giving the tank more hydraulic power, to distribute the load evenly over the bearings, and, more particularly, to dispense with the necessity of centre supports, which would be necessary if a flat bottom were used. It also prevents the accumulation of sediment which is the breeder of disease in many reservoirs. The tank is supported on an octagonal shaped stand of substantial masonry; the first 20 feet is built of stone about three feet thick, on top of this is 30 feet of brick work, and in each angle of the octagon is a solid pier three feet by four feet, on which rests the eight bearings of the tank, thus elevating it to a height of 50 feet above the ground. These eight bearings or carrying brackets consist of gusset plates $\frac{3}{8}$ inch thick by 7 feet long, with two angle bars 3½x3½x$\frac{3}{8}$, and a bottom bearing plate 12x15x½ inches, which rests on the piers—all tightly riveted together and to the side of the tank, as shown in the blue prints. Inside is a dish-shaped float of steel with capacity sufficient to displace enough water to overcome the weight of the rod, which is produced through the roof to indicate the water level. At the top of the tank is attached an overflow pipe, and at the bottom a steel down-pipe 2 feet in diameter, tapering to 10 inches at the main.



The whole is neatly and substantially enclosed in framework, which is double lined with matched lumber, and shingled on the outside, thus protecting it from the frost and the extreme heat of summer. In the connection between the tank and the main is a valve which is closed in case of fire, and the pumps act directly on the mains, and any desired pressure may be obtained.

This system of storage commends itself in many ways. Where nature has not provided an elevation, it is cheaper than any other. There is little or no evaporation, and it is much to be preferred to a stand pipe, as it dispenses with the necessity of constant pumping, which is a great consideration in a small town. It is protected from the frost, and is in no danger of being tipped over by the wind when empty; and besides furnishing pressure sufficient for all domestic service, it holds a supply with enough elevation to extinguish any ordinary fire without the use of the pumps.

The extent of piping covers about 20,000 lineal feet; this is provided with valves placed so that any portion may be shut off for repairs. The hydrants are placed about 500 feet apart, and have double hose attachments.

Pipes for this purpose are usually cast in lengths of 12 feet, and should not deviate more than 5 per cent. below the following standard weights:

10	inch	pipe,	60	lbs.	per	lineal	foot.
8	"	"	45	"	"	"	"
6	"	"	30	"	"	"	"
4	"	"	20	"	"	"	"

The specials should be of slightly heavier design, and all should be subjected to a hydrostatic pressure of 300 lbs. per square inch, and coated inside and out with tar, laid on hot before leaving the foundry.

The operation of pipe laying is conducted as follows: Trenches are excavated to a depth of 4 feet, into which the pipes are lowered by means of ropes. When the spigot end has been placed in the bell it is followed by a coil of yarn, which is driven to the inner end of the bell to prevent the lead entering the pipe. Around the joint there is placed a rope-like sack of wet clay, leaving a small opening at the top to admit the molten lead. When the space has been filled, the sack is removed and the lead is driven firmly to place by means of caulking tools. The trenches are then filled, having the earth well rammed around and on top of the mains.

At the final test, which was conducted by Mr. Galt in the presence of a large number of citizens, the system was found to give the best of satisfaction. By means of the tank pressure alone water was thrown over the roofs of the highest buildings, and when the pumps were used a very much greater height was attained; and now the citizens of Amherstburg, including even those who opposed the scheme, boast of a cheap and efficient system

of waterworks, and claim that in no other town are the requirements better met with.

About sixteen miles east of Amherstburg, on the M.C.R.R., and in the centre of a rich agricultural county of the same name, is the enterprising little town of Essex. At this place the scheme met with considerable opposition, but after a few open discussions on the matter the by-law was submitted and carried by a vote of over two to one; upon which Mr. Galt was engaged as engineer, and operations commenced at once.

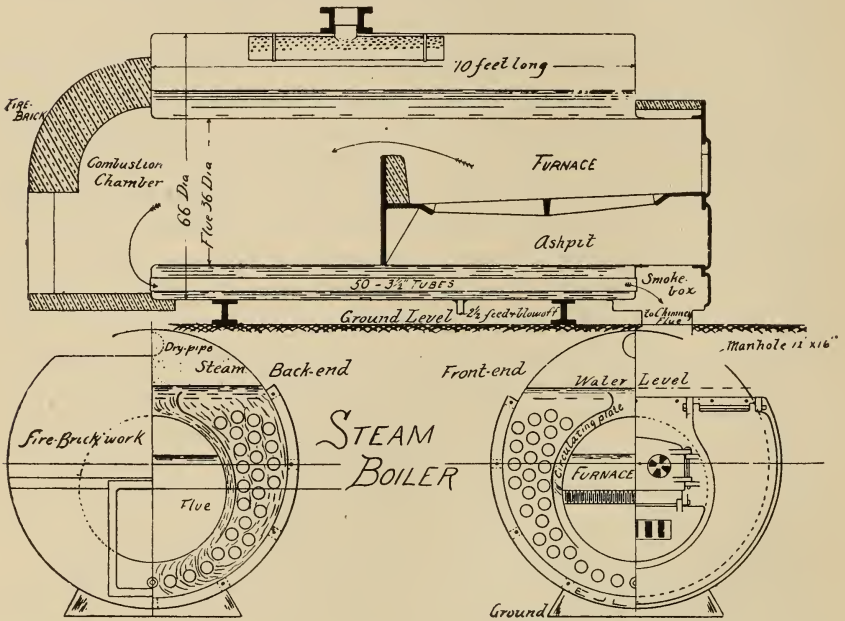
Here the problem of water supply was a somewhat difficult one. As there is neither lake, river, nor spring to draw from, boring had to be resorted to, and fortunately in a convenient part of the town three good wells, 13 feet apart, were struck at a depth of about 110 feet. These were cased with iron down to the rock, but the water rose only to within about 32 feet of the surface. Now, as no pump can lift water economically more than 25 feet, this involved another difficulty, which was overcome in the following manner: In order to secure a permanent supply of water for the pumps, around these three wells was dug a large well 25 feet in diameter and 50 feet deep, lined throughout with brick one foot thick, laid in Portland cement. The bottom is made of cement concrete 9 inches thick, through which the pipes flow, and the water stands in the well at an average depth of 18 feet. At the side of this well is sunk a vertical elliptical shaft 10x14 inches and 25 feet deep, lined throughout the same as the well; into this the pump is lowered, thus bringing it to within a few feet of the surface of the water. This incurred considerable expense, but the plan met with success, and an abundant supply of good water was obtained.

The pumping engine is similar in capacity and build to the one before described, and access to it is gained by means of a Barnum No. 10 spiral stair. As there is no chance at this depth for draining off the oil drippings and the condensed steam from the cylinders, it is caught in a sump hole at the side of the pump, from which it is thrown out into a drain by means of a steam ejector.

The pump is fed by steam from a horizontal boiler 5½ feet in diameter and 10 feet long, with an internal fire-flue 3 feet in diameter, around and underneath which is placed forty-six 3½-inch flues. The draught passes through the fire-flue to rear of boiler and returns through the tubes to the smoke-box in front, and thence to chimney.

As will be seen from the cut, the furnace front, smoke-box, and combustion chamber in the rear, together with the boiler, are all in one, giving the whole a neat and compact appearance. It is easily fired, has a good draught, and has been found to give the best satisfaction. It was designed by the engineer, and is specially adapted for waterworks service, as it is a quick steam maker. This quality it has from the fact that the source of

heat is near the surface of the water in the boiler, where all the hot water tends to collect, thus enabling it to make a considerable steam before all the water has been heated to the point of evaporation. Scaling is prevented by means of circulating plates, which partially envelop the fire-flue a few inches away from it. This plate is open at the bottom, and rises nearly to the surface of the water, by which it will plainly be seen that the water on each side of the fire-flue is kept in a circular motion.



The boiler and pump rooms, as in the previous case, are of brick, and are connected with a neat dwelling for the use of the engineer in charge.

The system consists of about 22,000 lineal feet of piping, with the necessary hydrants and valves, and also an elevated storage tank, same as shown in cut in connection.

Near the pumping station, for the convenience of the fire department, is erected a reel house and hose tower. The tower is 60 feet high, and is provided with an apparatus for drawing the hose up to dry. The department is furnished with 1000 feet of hose with all the latest improved attachments, and two hose reels which are operated by hand.

The final test, which was conducted by Mr. Galt, was a repetition of the success met with at Amherstburg, and the system has been found to even more than fulfil the highest anticipations of its promoters; and the citizens now congratulate themselves on their fire protection and domestic water service.

DIAGRAMS.

By John A. Duff, B.A., Grad. S.P.S., Fellow in Engineering.

From the time when man first invented picture-writing up to the present day, diagrams have been extensively employed as a means of communicating thought and of individual study.

Much of the time allotted for the reading of this paper might be occupied in giving instances of the use of diagrams in the arts and sciences, and in every-day life; but as it is intended to treat of the nature of diagrams rather than their application, no such enumeration will be attempted.

The examples which are given for the purpose of illustration are drawn almost entirely from Mechanics—though this is by no means the only science in which diagrams play an important part. In these examples the object is not to prove theorems in Mechanics, but merely to elucidate the nature of the diagrams employed in the proof. An exception has, however, been made in the case of the funiculiar polygon, the importance of the proposition proved by it seeming to warrant special mention.

A Diagram has been defined to be "a figure drawn in such a manner that the geometrical relations between the parts help us to understand relations existing between other objects."

The Diagram is of great value as an instrument of scientific investigation. Appealing directly to the eye, and presenting the argument in a concrete, realistic form, it makes it more definite and intelligible. By reference to letters or symbols placed at convenient points or lines of the diagram, the language in which the argument is stated is rendered more concise; and by the limitation placed upon our thoughts, they are more easily concentrated on the problem before us.

Diagrams are classified according to the manner in which they are intended to be used. Those which are not essential to the argument, and which are intended merely to afford a visual representation of the subject, are called Illustrative Diagrams or Diagrams of Illustration. The figures of Euclid furnish a familiar example. In this class of diagrams the argument proceeds by pure logic, and the diagram is satisfactory if the representation is clear.

The other class of diagrams consists of those which are drawn in such a manner that the magnitude of any quantity represented in the diagram may

be obtained by direct measurement. Diagrams from which measurements are intended to be taken are called Metrical Diagrams. It is essential that they should be drawn as accurately as possible, clearness being of secondary importance. Illustrative Diagrams which are sufficiently accurate may be used for measurement, and Metrical Diagrams which are sufficiently clear may be used for illustration.

Those methods in which Metrical Diagrams are employed are called Graphical methods. There are two systems of Graphics: in one the diagram is used for the purpose of calculation, in the other merely for the representation of results.

The method of Graphical Representation depends upon the fact that magnitudes can be represented by lines as well as by numbers. If a certain length be taken to represent unity, twice that length will represent two, three times that length three, and so on. The *scale* to which the drawing is made, is indicated by giving the length which is taken to represent unity, or (which is the same thing) by giving the number of units represented by one inch on the paper.

The simultaneous values of two independently varying quantities may be represented graphically by employing the Cartesian system of co-ordinates, one quantity being represented by the ordinate, the other by the abscissa of a point. For example, in Statistics, if it is desired to represent the population of a country for a series of years, the years may be represented by the abscissæ, and the population for each year by the corresponding ordinate.

The velocity-space and velocity-time diagrams employed in Dynamics are examples of Graphical Representation. In velocity-time diagrams the abscissæ represent times, and the ordinates velocities. The scale of the one will be so many *seconds* to the inch, and of the other so many *feet per second* to the inch. Accordingly, if the velocity of a particle at different instants has been determined by calculation or observation, and the results plotted on a diagram in the manner indicated above, a series of points will be determined such that the ordinate of each point represents the velocity at the time given by the abscissa. The curve passing through these points is called the velocity curve, and, when drawn, the velocity at any instant may be found by measuring the length of the ordinate whose abscissa represents that instant. In the same manner, an acceleration-time diagram may be drawn in which the ordinates represent the acceleration of the particle at the different instants of time. If the scale to which time is drawn is the same in each, the two diagrams may be superposed so that different lengths on the same ordinate represent the velocity and the acceleration at the same instant.

In velocity-space diagrams, the velocity and the distance traversed are taken as the independent variables. The abscissæ represent distances, and the ordinates velocities, just as in the velocity-time diagrams. Acceleration-space diagrams may be drawn and may be combined with velocity-space diagrams in the manner indicated for acceleration-time diagrams.

It follows from a consideration of the above examples that if the ordinates representing a number of suitably chosen and known values of any varying quantity be constructed, and the curve passing through their extremities be drawn, any intermediate value may be determined directly by scale. In this manner interpolation may be performed without the use of numerical tables.

One advantage of Graphical Representation is that it affords a simultaneous view of the different values, by means of which a more intelligent comparison may be instituted between them. If several values calculated from a formula be plotted by the co-ordinate method, the curve joining them presents a picture of the law which the formula represents. If the isolated results of experiment are plotted, the curve joining them may enable us to deduce the formula which embraces such results.

Another advantage of Graphics is the flexibility of the unit of measurement. It is known that numerals do not convey any definite idea of the magnitude of a very large quantity, much less of the relative magnitude of two or more very large quantities. But if a small linear unit is chosen, very large quantities may be represented graphically by lines of moderate length, and a good idea of their relative magnitude may be obtained. Similarly, by choosing a large scale a better comparison may be instituted between very small quantities represented graphically than when represented numerically.

The method of Graphical Representation is frequently employed in the observation of phenomena. Such diagrams are usually described automatically, and in many instances furnish the only accurate means of measuring the quantities involved. In most cases, the mechanism is so arranged that a card or strip of paper moves with a known uniform velocity in a given direction, while at the same time a pencil which marks on the card moves in the perpendicular direction, in accordance with the variations in the phenomenon observed. Thus the pencil traces out a curve such that each ordinate represents the magnitude of the quantity observed at the time or place indicated by the corresponding abscissa. For example, the Indicator Diagram of the steam engine furnishes a means of measuring the working pressure of the steam for every position of the piston, from which data the efficiency of the steam engine may be calculated.

It has likewise been customary for many years to record various

vibratory movements by means of Diagrams. Thus, the vibrations of sounding bodies have been recorded by passing a plate of smoked glass under a pointer attached to the vibrating body. This method is as truly a writing of sound vibrations as the method of the phonograph, and it is most probable that this use of Diagrams suggested to the inventor of that remarkable instrument the idea of writing sounds in wax.

Graphical Calculus is the method of using Diagrams for the purpose of calculation. For example, to find the square root of n, having chosen the scale, measure off on a straight line the distance which would represent $n+1$. On this line, as diameter, construct a circle, divide the diameter into two segments of length, n and 1, and through the point of division draw the chord perpendicular to the diameter; then half the length of this chord is the square root of n.

Thus the object of the Graphical Calculus is to construct a Diagram in such a manner that certain unknown quantities may be determined by direct measurement. The object of Graphical Representation is simply the representation of results. Hence diagrams and methods which are useful in Graphical Representation may not be suitable for Graphical Calculation. In the example of the Graphical Representation of velocities which has been given above, the magnitude is represented by the ordinate to the curve, but the direction and sense are not indicated. Accordingly, though this method may be convenient for the representation, it is not adapted to the calculation of velocities, except in the case of constrained motion, such as occurs in machines where the direction and sense of the motion are determined by geometrical conditions.

In order to fully represent a velocity by a straight line, recourse must be had to the theory of vectors. Any quantity which may be specified by magnitude, direction, and sense is called a vector quantity, and lines representing such quantities are called vector lines. Displacements, forces, velocities, accelerations, are examples of vector quantities.

Vector Diagrams are those which consist of vector lines. The principal problem connected with vector diagrams is the determination of the resultant of a set of displacements, forces, or other vector quantities. A convenient starting point having been chosen, let the vector line of one of the quantities be drawn, and from its extremity the vector line of another, and so on until all the vector lines are drawn. The figure so formed will be, in general, an open polygon, and the resultant will be represented by the vector line joining the initial to the final point.

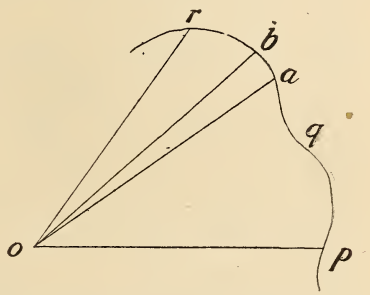
This proposition is self-evident in the case of displacements, and by analogy it may be inferred to be true also for other vector quantities. The best proof, however, that it applies to other vector quantities is in the fact

that all propositions logically deduced from it are found to agree with the results of experiment and observation.

In considering the relation which acceleration bears to velocity, it may be convenient to represent the velocity at each successive instant. If the velocity vary in direction, and if the velocity vectors for each instant be drawn from any origin, a series of radial lines will be obtained, which are indefinitely close to one another, and the locus of whose extremities will form a curve which is called the Hodograph. If the velocity does not vary in direction, the radial lines will be coincident, and the Hodograph will be a straight line.

In *Fig. 1* let *o* be the origin from which the velocity vectors are drawn; *pqr*, the locus of their extremities, will be the Hodograph. Let *oa*, *ob*, be the velocity vectors at the beginning and end of a very small interval of time δt. The velocity which must be compounded with *oa* in order to produce the velocity *ob* will be represented in magnitude, direction, and sense by the velocity vector *ab*. That is to say, *ab* is the vector of the change in the velocity in the time δt. Hence $\frac{ab}{\delta t}$ is the average rate of change of the velocity during the time δt, and, since δt is very small, $\frac{ab}{\delta t}$ may be taken for the acceleration during the time δt. But $\frac{ab}{\delta t}$ is also the velocity with which the Hodograph is described. Hence the velocity with which the Hodograph is described is equal to the acceleration of the motion.

Fig. 1



Since the direction and magnitude of the velocity are given by the tangent to the path and the speed with which the path is described, and since the direction and magnitude of the acceleration are given by the tangent to the Hodograph and the speed with which the Hodograph is described, the acceleration is the same function of the Hodograph as the velocity is of the path. Accordingly, the Hodograph is sometimes called the *curve of acceleration.*

Graphical methods have been more generally employed in Statics than in Kinematics or Dynamics, because in Statics the motion of bodies is not taken into consideration, and the diagrams are less complicated. In fact,

the most satisfactory proof of the principal problem of Statics is by the Graphical method. As it furnishes an excellent example of Graphical analysis, it may not be out of place to reproduce it here.

The problem is "To determine the resultant of a set of forces acting in one plane on a Rigid Body."

A Rigid Body is an ideal substance which is perfectly stiff, or in which there can be no relative motion between the parts, however small those parts are supposed to be. Since there can be no change of shape in a Rigid Body, the effect of any force acting on a Rigid Body will be the same at whatever point in its line of action the force is supposed to be applied.

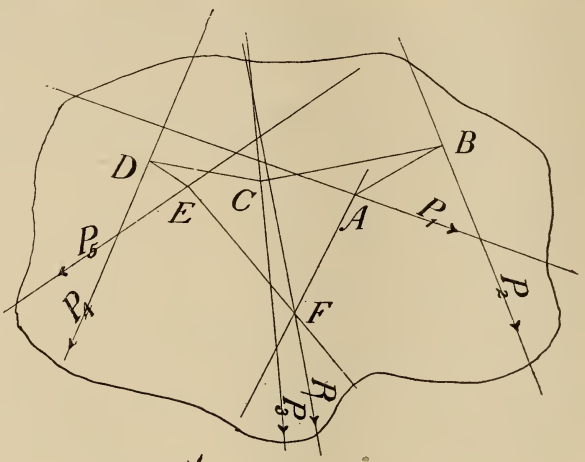
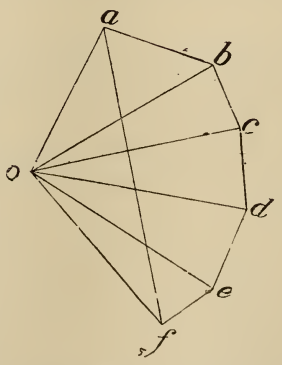


Fig. 2

Any force is fully described if the magnitude, direction, sense, and point of application are given. A force is a vector quantity in so far as it involves magnitude, direction, and sense.



Forces lying in one plane and acting on a Rigid Body may be divided into two classes, according as their directions do or do not all pass through one point. When the directions all pass through one point, all the forces may be considered to be applied at that point, and their resultant may evidently be applied at the same point. The magnitude, direction, and sense of the resultant may be determined by applying the theorem of the vector polygon. The resultant will then be fully determined.

When the directions of the forces do not all pass through one point, to determine the resultant:

In *Fig. 2* let P_1, P_2, P_3, P_4, P_5 be a set of forces acting in the same plane on a Rigid Body, but whose directions do not all pass through one

point. From any point a* draw ab the vector of P_1, bc the vector of P_2, cd of P_3, de of P_4, ef of P_5. Then $abcdef$ is the vector polygon of the forces P_1, P_2, P_3, P_4, P_5. In the plane of the vector polygon choose any point O and join oa, ob, oc, od, oe, of.

In the line of action of P_1 take any point A. Through A draw FA parallel to oa, and AB parallel to ob, intersecting P_2 in the point B: through B draw BC parallel to oc, intersecting P_3 in C: through C, CD parallel to od, intersecting P_4 in D: through D, DE parallel to oe, intersecting P_5 in E, and through E, EF parallel to of. $FABCDEF$ is called a *funicular polygon*, of which the first and last lines are FA and EF, and of which the point o is the *pole*.

The resultant of the forces P_1, P_2, P_3, P_4, P_5 will be represented by the vector line af, and its direction will pass through the intersection of FA and EF.

The body being rigid, the force P_1 may be considered to be applied at any point in its line of action. Let it be applied at A.

Referring to the vector polygon aob, it will be seen that the force P_1 applied at A, and whose vector is ab, may be resolved into two components acting at A whose vectors are ao and ob. But the force acting at A whose vector is ao must act along FA, because FA was drawn parallel to ao, and the force whose vector is ob must act along AB, because AB was drawn parallel to ob. Accordingly, instead of the force P_1 there may be substituted a force along FA whose vector is ao, and a force along AB whose vector is ob. In the same manner, the force P_2 may be supposed to be applied at the point B; and by referring to the vector triangle boc, it may be seen that instead of P_2 there may be substituted a force along AB whose vector is bo, and a force along BC whose vector is oc. Similarly, instead of P_3 there may be substituted a force along BC whose vector is co, and a force along CD whose vector is od: instead of P_4 a force along CD whose vector is do, and a force along DE whose vector is oe: and instead of P_5 a force along DE whose vector is eo, and a force along EF whose vector is of.

But the force along AB whose vector is ob is balanced by the force along the same line whose vector is bo, the force along BC whose vector is oc is balanced by the force whose vector is co, and so on. Of the ten forces which have been substituted for the five original forces, there are left the two unbalanced forces, ao acting along FA and of acting along EF. These two forces may be considered to be applied at F, the intersection of FA and EF. Their resultant will also act at the same point, and its vector will be

* In what follows the order in which the letters are given indicates the *sense* in which the line is taken.

given by the line *af*. Hence the resultant of the set of forces, P_1, P_2, P_3, P_4, P_5, passes through *F*, the intersection of the first and last lines of the funicular polygon, and its vector is *af*, the line joining the first to the last point to the vector polygon.

If the line *af* passes through *o*, the pole for the funicular polygon, then *FA* and *EF* either coincide or are parallel, because each was drawn parallel to the line *oaf*. If *FA* coincides with *EF* the funicular polygon is said to close, and the set of forces reduces to two forces whose vectors are *ao* and *of*, and whose line of action is in *EA*. The resultant is evidently that force along the line *EA* whose vector is *af*. If *f* coincides with *a*, this resultant becomes zero and the set of forces will be in equilibrium. When *f* coincides with *a*, the vector polygon is said to close. Hence the conditions of equilibrium are:

(1) That the funicular polygon should close.

(2) That the vector polygon should close.

Again, if *FA* is parallel to *EF* but does not coincide with it, the set of forces will reduce to two parallel forces. If *f* does not coincide with *a* these two parallel forces will be unequal, and will have a single resultant, a point whose line of action may be obtained by choosing a new pole *o'* and drawing a new funicular for the vector triangle *aof*. But if *f* coincides with *a*, the set of forces will reduce to two equal and parallel but opposite forces, acting along *FA* and *EF*. Such a pair of forces form a couple and have no single resultant. Hence the conditions that a set of forces should reduce to a couple are:

(1) That the vector polygon should close.

(2) That the funicular polygon should not close.

The point *A* might have been taken anywhere on P_1, and accordingly an indefinite number of funicular polygons might have been constructed with the same pole *o*, but the corresponding sides in each would have been parallel. But if funiculars be drawn for two different positions of the pole *o*, the corresponding sides in each will not be parallel. The pole *o* may be chosen anywhere in the plane of the vector polygon, and the starting point *A* may be taken anywhere along the line of action of P_1; accordingly, there may be constructed an indefinite number of sets of funiculars, and there may be an indefinite number in each set, but all the polygons of each set will have their corresponding sides parallel.

It will be seen that the Graphical Calculus possesses the same characteristics which belong to the method of Graphical Representation.

The system of thought is purely synthetical—before any unknown quantity can be used, it must be determined. This may seem at first sight to be an inconvenience when compared with Analytical methods in which

the unknown quantities which are used in the investigation, but not sought after, may often be eliminated. But Graphical methods being more direct require the use of fewer of these unknown quantities, and the calculation of them, Graphically or otherwise, is often a necessary step in the calculation of the desired quantity. The accuracy of the calculation is limited by the accuracy of the draughtsman and his tools. It is generally sufficient for practical purposes; and whilst the practical engineer is continually becoming more expert with his drawing instruments, he is at the same time becoming less familiar with Analytical methods and formulæ.

Graphical Calculus aims at giving general methods, at formulating a routine to be followed in the solution of each problem, but it cannot give general results—results by means of which particular problems may be solved by merely inserting particular values. But to the engineer this is no serious disadvantage, for he has usually to deal with particular problems, and he can employ the general methods of Graphics to obtain the particular results which he requires.

If the results of Graphical Calculus are less general in their application, the meaning is not half concealed in a mass of formulæ of which the practical engineer knows little or nothing; and to understand Graphical methods, it is not necessary to have that extensive knowledge of Mathematics which is so essential to Analytical investigations, and which requires years of study to obtain.

Many advocates of Graphical methods have spoken very disparagingly of Analytical, and those who follow Analytical methods have a tendency to ignore Graphics. The proper view is to consider the two systems as complementary, and not opposed to each other. There is no student of Graphics who is not benefited by an extensive knowledge of Analytical methods, and no student of the latter who should not also study Graphics. The one furnishes a most useful check upon the accuracy and elucidates the methods of the other, and no important engineering work should ever be undertaken, in the calculations for which both methods have not been employed.

RETRACING OLD COMPASS LINES.

By J. L. Morris, C.E.

The compass used by land surveyors in making new surveys and retracing old ones has generally a needle five or six inches in length, about one-quarter of an inch in depth, and one-sixteenth of an inch in width. The needle tapers towards the ends, and becomes nearly a fine edge.

The graduation is made to half a degree, and with this fine needle, as low as ten minutes, and even five, can be read between the divisions. Older compasses had sights screwed to the compass box, which were very troublesome in a rough and thickly-wooded country, owing to their catching in the brush and striking projections, but the folding sight has done away with this objection. A staff cut in the woods and fitted to a steel point carried by the surveyor is satisfactory. Until a few years ago the majority of surveyors showed their courses as magnetic without giving the variations of the compass from true north; and in cases where the original boundaries have been destroyed, it is only a question of approximately determining the original boundaries, even with a correct point to start from; the nearness to a correct line depending upon the number of magnetic observations taken by the surveyor in that locality. Having no information as a basis for retracing my first compass line, enquiries were made from three surveyors, with the following result: (1) "I cannot tell you accurately what the change is, but somewhere about a degree in every twelve years." It was found that the change was a degree in every eighteen years. (2) "There is no reliable change of variation to suit compass lines owing to the careless work of surveyors forty or fifty years ago." It has been found that there is a change which suits the great majority of compass lines. (3) "Compasses differ in their magnetic north, and the change of variation at the same place may vary with different compasses from two and a half to four and a half minutes every year." So far the work by five or six different surveyors has been found to agree with the same change of variation. The changes in variation are placed under four heads: Irregular, Diurnal, Annual, and Secular.

You have observed, if retracing a line in a hilly or mountainous district, that at times the needle of your compass will differ two or perhaps fifteen degrees from your course of the last sight on the line. This may be

attraction from iron in the vicinity, or, if not in a rocky, broken country, might be credited to magnetism in the air from some thunder or other magnetic storm. There has been one case where the needle has pointed at right angles to its true course. It is not always expected that the needle will become lively and sensitive under this attraction, but at times will assume a very dead manner, and hard to move out of its course. You may think that the pivot on which your needle swings may be at fault, but will finally conclude that there is a magnetic pole directly under the point of your staff. These may be the causes for Irregular changes.

Diurnal or daily changes will never be noticed during work in a level country, but probably after running over a hill, and a few hours afterwards looking back from another hill, you will find that the course now reading on your compass will not agree with the line back, and may require a change of about fifteen minutes to do so. The effect is that you arrive at your destination with a line of the same course at the ends and curved in the middle. A continuous line from day to day would take the form of a snake. This change in variation explains the reason why a transit line will cross and recross a compass line. In practice, this change of variation does not interfere with the work of a surveyor retracing an old line.

The Annual change is a variation in the Diurnal change, differing in summer and winter, but does not affect us in our work. If correct observations were taken from year to year, it would be observed that the magnetic bearing of the same line will change from year to year, and is known as the Secular Change of Variation. The following table, formulated from a few cases in practice, gives the date of the original survey, magnetic course of line, district, date of retracing, and the course of retraced line:

Date.	*Course.*	*District.*	*Retraced.*	*Course.*	*Change.*	*Per Year.*
1841	*N*21°*E*	Ottawa River, Renfrew County.	1891	*N*23°45′*E*	2°45′	3′.3
1845	*N*21°*E*	Petewawa River.	1891	*N*23°30′*E*	2°30′	3′.3
1846	*N*21°*E*	Ottawa River, Renfrew County.	1889	*N*23°15′*E*	2°15′	3′.1
1846	*N*21°*E*	Petewawa River.	1891	*N*23°30′*E*	2°30′	3′.3
1874	*N*88½°*E*	Pembroke.	1891			

It will be observed that the changes in variation show a nearly uniform change. Considering that the question of retracing old compass lines is now becoming of greater moment, owing to the increase in value of property and timber, it would be of great service to surveyors in certain districts to have the variation at different places and at regular periods

ascertained. This information, compiled into a table of "Changes of Variation," would be of great service to coming surveyors. It would be found that the work done with a compass, rather than being under mistrust, would be satisfactory and more correct.

A SHORT PRACTICAL ESSAY ON "THE SEA AND ITS WAVES."

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By V. G. Marani.

The subject upon which I am about to enter is one which, although vastly interesting, is generally paid little or no attention to, a fact which, if we consider, is not at all surprising, as busy shoremen, when on land, find so much to interest and occupy time and attention that they scarce give a thought to what at first sight appears as a vast waste of gloom and solitude.

The ocean, occupying about four-fifths of the entire globe, is in itself a perfect world of life, though rarely of peace. Clever scientists tell us that the ocean water is composed of 28 elements, the principal being of course those which give it its liquid state; namely, *oxygen* and *hydrogen*, in which are contained *chlorine*, *nitrogen*, *carbon*, *bromine*, *iodine*, *fluorine*, *sulphur*, *phosphorus*, *silicon*, *sodium*, *potassium*, *boron (?)* *aluminium*, *magnesium*, *calcium*, *strontium*, and *barium*, including *silver*, *iron*, and *copper*. These various substances, however, exist only in infinitesimal proportions; of the metals, silver perhaps being the most abundant, as Reclus informs us that the ocean contains 2,000,000 tons of silver. Sodium chloride (common table salt) forms three-fourths of the salt state of the ocean.

If the waters of the ocean were to evaporate, we should have left an average of about 2″ inches to every fathom of water; or, taking three miles as the average depth, were the ocean then to evaporate, we should have left a layer of salt about 230 feet in mean thickness. The saltness or (specific gravity) of the ocean, however, varies in all parts according to the amount of fresh water contributed by rain or rivers, and the direction of currents and counter currents. The average specific gravity of oceans with deep basins is 2.8 per cent. more than the same bulk of distilled water. In the Mediterranean, however, the specific gravity is 2.9 per cent., more owing probably to the evaporation, caused by the warm climate to which this sea is subjected, slightly exceeding the amount received from rivers and rains. The exact reverse takes place in the Black Sea, where the specific gravity is only 1.6 per cent., owing to the large amount of fresh water received from its numerous rivers. It has also been an established fact that the waters of the Southern Hemisphere are considerably less salty, and therefore lighter, than those of the Northern Hemisphere. We can now proceed to discuss a subject that will involve what has, as yet, only been approximately

ascertained, namely, the greatest depth of the ocean. One of the deepest soundings taken with success was between the Pacific and Indian oceans, south of the East Indian Islands, by Captain Riggold, who found bottom at 8¾ miles.

Young, during his sounding cruise, gave the North Atlantic a mean depth of 3,280 feet, and in the South Seas his estimated mean depths ranged from 19,500 feet to 22,000 feet. But Sir John Herschell, for his practical use, took the probable maximum depth of the ocean as a little under 5 miles. However, results obtained at such depths must be very vague, it being practically unsafe to rely on the accuracy of soundings (by mechanical means) at a greater depth than 2 or 3 miles. Many efforts have been made to sound some parts of the Pacific Ocean, but, as yet, all have failed to gain bottom. The currents of the ocean, in turn, also form a leading feature in the study of the sea and its waves. Currents can be divided into two great classes, namely, drift and stream currents; the former moving in a direction more or less parallel to the wind in each district, and which, when deflected by meeting with an obstacle (such as an island or line of coast), flow on in a new direction until their impetus is expended under the name of stream currents The currents of the ocean are very numerous, some of the most important being the Gulf Stream, Equatorial, Humboldt's, and American Arctic currents, including several others, each and all of which faithfully, and to fixed laws, perform their principal functions in climatizing countries and islands.

In low latitudes, all round the world, we meet with westerly currents, and in every case there is an easterly counter current flowing close along the Equator between the drift currents of the two Trade Winds. In the middle latitudes, however, the currents are reversed, and are generally easterly. In fact, in each of the five great oceans vast bodies of water are continually circling round in eddies, the Equatorial current taking the water westward, and the return currents, like the Gulf Stream, bringing it eastward again. This may be expressed simply by the following theorem from "Dr. Haughton's Physical Geography": "Given a permanent system of constant continuous circulation in any ocean, if any vertical plane be supposed drawn across the ocean, equal quantities of water must cross that plane from right to left, and from left to right, in a given time; for, if possible, let it not be so, then there will arise a difference of sea level at the two sides of the supposed plane, and the hypothesis of constant continuous circulation will become impossible."

Having roughly discussed the density, depth, and currents of the ocean, we now come to the phenomena of sea waves, the formation, height, and velocity of which are either more or less influenced by the above subjects.

Landsmen are wholly indebted to the sailor for at least the courtesy of giving "faith and full credence" to what they tell us about what they have actually seen and suffered, and to me nothing seems so obnoxious and disheartening as the reception which these "stay-at-home travellers" generally exhibit in their criticism of what seamen tell them as to the height of sea waves, etc. But once again to our subject. The sea is very seldom, if ever, at rest, and even during a calm under the burning rays of a tropical sun the glassy surface is seldom motionless; for long swells, causing the ship to roll, are sufficiently perceptible to tantalize the sailor with the thought that the breeze which mocks his desires is blowing freshly elsewhere. We can quite easily understand that, were it not for the wind, the sea would (under natural circumstances) present a smooth glassy surface, and therefore the wind now aiding, now retarding the currents, or ebbing and flowing, raises the sea into waves, more or less high, which roll regularly onward, or are dashed against or across one another. Owing to the sudden changes of wind or other numerous causes, waves sometimes become so confused and irregular that it is absolutely impossible to ascertain their direction, height, or speed. Sometimes, by piling upon each other, they more than double their natural height, and at other times they equalize the surface by throwing billows into furrows. Now, as already stated, the specific gravity of the water is one of the great features in the height of waves, and according as to whether the water is more or less dense, so is it also more or less susceptible to motion. Hence, to an equal wind, the waves of Lake Superior would exceed those of a lake of sea water equal in area and depth.

The waves of the Mediterranean are far exceeded by those of the Atlantic, while these latter are also exceeded by those of the Antarctic Ocean, which spreads over an entire hemisphere. Admiral Smyth estimated the Mediterranean wave at about 20 feet from crest to hollow. Scoresby, in 1848, gave the Atlantic wave an average of 30 feet from crest to hollow; but Dumont d'Urville, an old sailor of yore, asserts having seen waves from 80 to 100 feet high, to the depths of which the ship descended as in a valley, and M. Fleuriost de Langle, attests the truth of his statement. By the appearance of a troubled sea, one might suppose that the waves travelled, but such is not the case; waves themselves do not travel, their movement horizontally being irregular, and the water practically remaining in the same place. But it is the motion only which goes on; and it is the foaming crest, which, curling over the summit of the wave, dashes down the slope in front, not infrequently carving for itself a path of wreck and destruction. The apparent displacement of billows can only approximately be ascertained; and as the depth of the ocean increases, the more approximate will be the results. The velocity with which this displacement takes place

undoubtedly depends mainly on the power and duration of the wind, but this velocity is greatly diminished by, and bears an ascertainable relation to, their magnitude and the depth of water over which they travel. It is said that the width of a wave (which is measured from trough to trough) is, on an average, about 15 times its height. Hence, if the average maximum wave be taken at 40 feet, it will, at its base, also extend over 600 feet or so of water.

Prof. Airey informs us that the displacement of a wave 100 feet in width and in water about 164 fathoms deep will be at the rate of about 15 miles per hour, and that a wave 674 feet in width, and over the surface of a sea 1640 fathoms deep, will move forward with a velocity of about 48 miles per hour. Thus, from investigation, we see that the Atlantic rollers of a mean width of, say, 200 feet, travel at the rate of about 40 feet per second (or 27 miles per hour).

Weber informs us that the motion of a wave can be felt in a vertical direction to 350 times its height. Therefore a wave 33 feet high will be felt at a vertical depth of about 2 miles. But at this enormous depth the motion must almost become an imaginary one, for below the surface this influence decreases in geometrical proportion. Taking a wave of about 40 feet high, it is said that the utmost disturbance of a water particle at a depth of 300 feet is not ½ inch from its mean position. Hence this shows that a mere surface effect is due to winds, and that the depths of the ocean are practically undisturbed by such causes. The actual force of wave motion can only be perceptible at about a depth of 30 or 40 fathoms. Since, therefore, we can by calculation infer the velocity of waves from their magnitude and the known depth of the ocean bed, it is easy to determine, by an inverse operation, what is the depth of the ocean itself, provided we know the rate of motion of the waves. And it is by this process that an approximate depth has been given to those parts of the Antarctic Ocean as yet never sounded by mechanical means.

Bache stated as one of the effects of an earthquake at Samoda, on the Island of Niphon in Japan, on December 23rd, 1854, that the harbor was first emptied of water, and then came in an enormous wave, which receded, leaving the harbor dry; this occurred several times. The self-acting tide-register at San Francisco, which records the rise of tide upon cylinders turned by clocks, showed that at that place, 4,800 miles from the scene of the earthquake, the first wave arrived 12 hours 16 minutes after it had receded from the harbor of Samoda. Thence it had travelled across the Pacific Ocean at the rate of 6½ miles per minute; the average depth over which this wave had travelled being about 14,000 feet. The *New York Sun*, in an article on "Sea Waves," informs us that carefully repeated

experiments made by an experienced English navigator at Santander, on the north coast of Spain, showed the crest of sea waves in a prolonged and heavy gale of wind to be 42 feet high, and, allowing the same for the depth between the waves, the result would be a total height of 84 feet from crest to hollow; the distance from crest to crest was found to be 386 feet. The s.s. Gallia, on a voyage to New York during a gale in January last year, was boarded by a sea that her captain estimated at 100 feet high, also stating that had she been boarded by another such sea she would surely have foundered. We have other instances of the size and power of waves recorded to us from the logs of some of our transatlantic steamers, which, compiled and built as securely as iron can possibly be, yet, alas! only too often come to sad distress.

Quite recently we had the case of the s.s. Vancouver, whose chart house, and, unfortunately, the captain, who had just entered it, were both washed overboard by the single force of one sea. The Sardinian also lately lost her funnel by a sea, which also flooded the fireroom, smashed several of her boats, and killed three men. The Rijnald from Antwerp to New York, by one sea, lost her wheel house, five boats, and port rail; another sea, apparently of greater violence, tearing away the remaining rail, crushing the iron trestle back, and disabling the steering gear. It is true that few vessels could ever hope to withstand the tremendous power of those swift monster seas but for their enormous strength and the fact that they rarely receive the full impact of the wave.

Thomas Stephenson estimated that the force of the sea against Bell Rock Lighthouse is about 17 tons per square yard. In the Island of Skenyvon the heaviest calculated pressure is about 3½ tons per square yard. With such forces, the displacement of blocks from all the exposed works (sea walls, breakwaters, etc.) at Kingstown, Holyhead, Portland, and other places, which to us seems impossible, is only child's play to the tempest waves. At Leghorn, on the coast of Italy, the Atlantic waves have been known to seize blocks of stone weighing several tons and hurl them like playthings on the dykes.

At Cherbourg, on the north coast of France (noted, after the labor of over half a century, for its immense artificial breakwater and fortifications for mounting 3,000 guns), the waves have been known to displace the heaviest cannon on the rampart. At Plymouth, a vessel weighing 200 tons was thrown to the very top of the dyke, where she remained erect and safe from the fury of the waves. At Bara Head, in the Hebrides, Thomas Stephenson states that a block of stone 43 tons in weight was driven more than 1¾ yards by the breakers.

At Peterhead, N.B., over 30 years ago, there was a great crowd of

people down near the beach one day watching the swells come in from the most severe storm on record at the time. About two hours before high water three tremendous waves rolled in, and, breaking on the beach, carried away 315 feet of a great bulkhead built 9½ feet above high water of the spring tides. One piece of the wall weighing 13 tons was carried 50 feet. Two hours exactly after high tide, three more waves came in of a similar character, but doing less damage. This was the first case on record in which the formation of big seas was connected with the time of the tides, but similar observations have been frequent since then.

It is on record that the waves of the German Ocean once broke in two a solid column of freestone 36 feet high and 17 feet in diameter at the base. The diameter at the place of fracture was 11 feet. At the top of Bound Skerry of Whalsey, in Zetland, the waves have broken out of their beds, which are 85 feet above the level of the sea, blocks of stone weighing from 8 to 10 tons.

At Tillamock Rock Lighthouse, situated in the Pacific off the coast of Oregon, a stone weighing 82 pounds was thrown by the force of the waves to the top of the lightkeeper's house, 110 feet above the sea level. During the same gale, the waves were so high that the water came down the chimney of the boiler-house of the fog siren in torrents and poured out through the tubes of the boiler. The chimney is 130 feet above sea level. The spray also entered the cowl of the chimney over the lamp, which is about 150 feet above sea level, and ran in streams to the bottom.

An instrument called the *marine dynamometer* has been made with a view to accurately measure the force exerted by waves. It has a known surface for the water to impinge on, the force of the impact being transferred to springs of known strengths. The distance to which the springs are compressed is self-registering. This instrument has recorded the force of the waves, not under extraordinary circumstances, as high as three tons to the square yard; and no doubt in exceptional cases this figure has been far exceeded. Smeaton, in his "History of the Eddystone Lighthouse," only too truly says, in referring to the power of waves, that "controlling these powers of nature is subject to no calculation."

It was during my last year's apprenticeship in the sailing ship firm of W. M. & Co., Liverpool, that the events I am about to narrate occurred. We left Hull, England, bound *via* Cape Horn for San Francisco, on the 2nd March, 1887, in the clipper ship, *Cedric the Saxon*, 1619 tons register, and truly one of the finest specimens in the merchant navy, being built by the late firm, John Reid & Co., of Glasgow, at a cost of $160,000.

How, like a living thing, she seems eager to get out of the musty docks; she frets her shapely sides; and how, after being towed well clear of

Spurn Head, she, scenting a fair nor'wester, gracefully spreads her sails, and, parting the seas with her clipper bows, bids farewell to England's shores!

Nought but the usual every voyage occurrences to record. In Channel at night great anxiety attends the sight of other vessels' lights, I having on one occasion counted no less than 198. The dangers of Channel over, we soon pass the Western Islands, and, as we near the tropics, we unbend our heavy canvas and replace it by a lighter and older suit. In the tropics the monotony of painting, overhauling of blocks, etc., which is only broken by the capture of a shark, turtle, or porpoise, the two latter making a splendid addition to our humble bill of fare; the former, when none other is to be had, also being acceptable, providing it be fairly young. With such and more numerous adventures than these we, after having struggled through the doldrums and southern tropics, find ourselves nearing the River Platte latitudes, where, as is generally the case, we had more wind than enough for our old sails, some of which we lost, to the silent but evident satisfaction of some of our tars, who, not forgetting the trouble they had bending them, would shake their heads and mutter, "I knew they would go; they were no use; ought never to have been bent," etc. A few nautical orders, followed by forcible words, has on such men a magical effect, and before long the ship is either in snug trim or hove to.

Soon a change of weather, and away we sailed, reaching the latitude of Cape Horn on our fifty-third day out. So far fortune had favored us; but as we neared this dreaded spot, we encountered strong westerly gales. For about three weeks we tacked, probably making by direct route about a true westerly course. The wind now greatly increased, and with it a sea of such force and violence that our galley and the after-part of the deck house were completely gutted, and we, now no longer able to tack, had to wear.

After about a week of hardships, such as only those who endured them can describe, we, to our dismay, began to realize that we were slowly but surely losing way; and that unless we were well to the southward of Cape Horn, we would inevitably drift on the rocky coast of some of the numerous islands. But on a Thursday night a change occurred, and none too soon, for, as the wind fell, we could distinctly hear in the distance the roaring and crushing of those enormous seas that, aided by a strong easterly current, were dashing most unmercifully on nature's rock-clad coasts. With what anxiety we awaited the coming morn as each monster sea raised us high, perhaps only to dash us with double violence on some hidden rock. Our barometer, reading about 27.60, continued to fall rapidly, as on, and with increasing velocity, came the south-easter. Taking no notice of a falling glass, we set all possible sail in order to further our distance from so dangerous a coast. Thus with fore and main lower topsails reefed main-

sail, main upper topsail, and foresail, our ship dived and plunged her way through the seas, now and again to meet some great monster, that with its force would cause her (as if stunned) to remain still, and then (like some animal fighting against an equal foe) tremblingly continue her way. But rapidly the wind increased, and with it our speed, which, becoming dangerous against so great a head sea, compelled us to shorten in the mainsail; taking about two hours to haul the sail up, and five more before we had it furled. We were all utterly exhausted, so much so that two of the men, from aloft, no longer able to endure the exposure, had to lie down and an apprentice fell to the deck, a height of about 50 feet. He was fortunately picked up before being washed overboard by a sea, but only to endure weeks of internal pain.

But how could so fierce a wind battle against such a sea and current without some striking change? The waters, by this contrary hurricane, were simply piled into enormous wall-sided seas. After rising to prodigious heights, these seas would curl over, rushing after the ship in a terrifying manner. We could not heave to. It was just as much as we could do (with the amount of canvas set) to keep sufficient speed on the vessel in order to outreach these curling crests. Saturday morning found all hands on the poop—none cared to go below—all too anxious for the safety of the ship and their own lives.

At 8 a.m. an Englishman and I took the wheel, with orders to keep the wind fair behind us. How fearful the motions felt to me as clinging to the wheel, I would feel my weight lifted almost off the deck as the ship plunged into the trough, and, unable to check her mad rush in a moment, would half bury her nose in the seething foam; while after her rushes, the crest of the monster sea she has just descended. But soon the ship shakes herself free, and with mighty but well-spent efforts rises to the summit of the next wave, where, being again exposed to the full fury of the blast, with creaking spars and well-strained sails, she continues her downward plunges. Such was our state until about 11 a.m., when my mate at the wheel requested a "relieve," as he wanted something to eat; the captain eyed him with disgust, passed a remark to the effect that "he ought to think of his grave, not his belly," and then gave the order for another man at the wheel. The "relieve" had just been at the wheel ten minutes or so when, chancing to look at him, I saw his face turn pale, and, giving a yell of warning, he fled. I had no time to consider; I instinctively clung to the wheel; I saw what was coming, and, for the moment, I felt how insignificantly small and helpless the ship was. As this monster sea approached us, I heard the mighty hissing and crushing of its dangerous crest; then, with a motion that was both confusing and sickening, the ship shot upward,

but alas! just too late. For one moment I felt the pressure on my back of the sea, which next moment carried both the wheel and me with it, and, raising me off the deck, finally left me clinging to the main rigging. The sea had passed, leaving behind a path of wreck and destruction. The ship, with her sails aback, now gathered stern way, and slowly began to bury herself in the foaming, boiling sea. It is now hard to say what we did; excited, nay, almost mad, each one did what he thought best for the safety of the ship. Tanks of oil were torn out of the paint locker, and, after having been gashed with an axe, were thrown into the sea. Braces and sheets equally shared the same fate, and the ship, relieved of her sails, before long rode more freely, head to wind. She was indeed a wreck; her wheel, skylights, boats, and skids had all been washed away, while the bulwarks and rails were bent and distorted into such shapes as even to put to defiance the skill of a blacksmith. Not only our old mate (a sailor of 40 odd years standing), but also some of our most experienced sailors, maintained that they had never seen before such a spell of weather, or seas so dangerous and of such magnitude, their estimation of the one which boarded us being between 60 and 70 feet from crest to hollow. The barometer during this hurricane fell to the low reading of 27.42. Truly nature's elements were at war.

Xerif al Edrisi, one of the most eminent geographers of the Arabs, in the middle of the twelfth century, at the Court of Roger I., King of Sicily, composed a work which he styled, "The going abroad of a curious man to explore all the wonders of the world." The Atlantic is thus noticed: "No one has been able to verify anything concerning it on account of its difficult and perilous navigation, its great obscurity, its profound depths, and frequent tempests, through fear of its mighty fishes and haughty winds; yet there are many islands in it, some peopled, others uninhabited. There is no mariner who dares to enter into its deep waters; or if any have done so, they have merely kept along its coasts, fearful of departing from them. The waves of this ocean, although they roll as mountains, yet maintain themselves without breaking; for if they broke, it would be impossible for a ship to plough them."

As we read these words, containing the ideas of bygone ages, it is with a feeling of pride and gratitude we acknowledge that to such men as Maury, Herschell, Scoresby, and others, we owe our present knowledge of the ocean with its once obscure secrets.

HYDRAULIC CEMENTS.

By Edward F. Ball.

Mr. President and Gentlemen,—This paper will be devoted to the discussion of the effect of impurities usually found in cement, with descriptions of tests for their detection. The literature on this subject is meagre and conflicting. Gillmore treats of the process of manufacture at some length; but as he was the pioneer in cement testing, this work is not up to date. Considerable information can be obtained from the pamphlets published by manufacturers and dealers; but as the writers are usually prejudiced in their opinions, these must be taken "with a grain of salt." Baker's "Treatise on Masonry Construction" contains much valuable information on the subject.

Space does not permit of a detailed description of the American and German methods of cement testing, but such information can be obtained from the work last mentioned. Directions for the American method are enclosed in the samples which accompany this paper.

Before entering upon the subject of impurities, it will be necessary to briefly refer to the process of manufacture and the chemical changes which occur.

PORTLAND CEMENT.

Artificial Portland Cement is made by *thoroughly* mixing together in suitable proportions *finely divided* clay and carbonate of lime (chalk, marl, or compact limestone), burning the mixture in kilns at a high temperature, and then grinding the burnt product to fine powder between ordinary millstones.

It is especially important that the ingredients be thoroughly mixed, finely ground, and correctly proportioned. No substance coarser than the one-thirtieth part of an inch will make cement, and the finer the ingredients are ground the better. Thorough mixing is even more important than correct proportioning, as the temperature in the kiln is not allowed to rise high enough to liquefy the mass, and, in order that the chemical changes may take place, the particles of clay and lime must be in close contact with each other; otherwise uncombined clay or lime will be left.

The first chemical change which occurs in burning is the expulsion of chemically combined water and carbon dioxide; thus calcium carbonate

$CaCO_3$, is converted into lime, CaO. The silica, SiO_2, which is present as silicate of alumina in the clay, is partly transferred to the lime, forming a double silicate of lime and alumina. A high temperature is necessary for the formation of this double silicate, but at a lower temperature the alumina, which was present in the clay as a base, plays the part of an acid, and, combining with the lime, forms aluminate of lime.

If the temperature is too high, a lime glass is formed which has no hydraulic properties; and if the burning be continued at this temperature, a solid crystallization between the silicates and aluminates of lime is formed, which also impairs the hydraulicity.

THEORY OF THE SETTING OF CEMENT.

This may be briefly described as the crystallization of the double silicate of lime and alumina.

IMPURITIES.

If by reason of imperfect proportioning, grinding, or mixing any portion of the lime fails to combine chemically with the silica or alumina of the clay, this is known as *free lime*, and, when the cement is fresh, it is in the form of CaO. Upon exposure to the air it absorbs moisture and becomes slaked; thus:

$$CaO + H_2O = Ca\ (OH)_2.$$

Upon still further exposure it slowly absorbs carbon dioxide and returns to its original composition, carbonate of lime:

$$Ca\ (OH)_2 + CO_2 = CaCO_3 + H_2O.$$

When present in the unslaked form, CaO, free lime is one of the most dangerous impurities in cement, as upon the addition of water it slakes and expands, thereby disturbing the setting of the cement. This slaking is not rapid like the slaking of rich or fat lime, and often is not apparent for the first day. It frequently happens that samples of cement will stand a good tensile strain at the end of 24 hours, while at the end of 7 days the test will be very low; sometimes below the 24-hour test. This generally indicates free lime, and in such a case the samples should be exposed to the air for a week and a second test made. If this test comes up to the standard the trouble is due to the presence of free lime, and the cement should be accepted, provided the other tests are satisfactory, on condition that it be spread out and exposed to the air for a week or more before use. If the lime have sufficient activity, thin cakes of the cement immersed in water for a week will show cracks; but if the lime is not present in sufficient quantity, or has not the necessary activity, no cracks will appear.

Mr. W. W. Maclay, an eminent authority on cement, recommends ex-

posing the pats as soon as they are hard to a high temperature, saturated with moisture for about three hours, and then boiling them for 24 hours. Free lime should not be present in excess of 2 per cent., especially if the cement be for use under water. It retards the setting of the cement and impairs its hydraulicity. When present in considerable quantity, the cement will disintegrate on immersion unless first allowed to become quite hard in air.

In determining the amount of free lime in cement by chemical analysis, it is customary to find the amount of CO_2 on the supposition that the lime is in the form of carbonate, and then calculate the amount of lime, 1 per cent. of CO_2 indicating 1.3 per cent. of CaO. This, however, is a very unreliable method, as before the lime can be converted to $CaCO_3$ it must first be hydrated and then carbonated. This requires a long time, if exposure to the air is relied upon to effect the change, as is usually the case. Hydrogen sulphide, H_2S, is frequently evolved with the carbon dioxide, and this also affects the accuracy of the test In the absence of any better method, the writer has determined the amount of free lime by expelling the CO_2 with dilute acid. The acid and cement were carefully weighed, before and after mixing, the difference indicating the amount of CO_2. The average of a number of tests should be taken, as the process requires great care to obtain accurate results.

Magnesia is another dangerous impurity in Portland cement. It may not prevent the cement from setting and becoming apparently as hard as though it were absent. For a long time it may remain inert, and perhaps for months there may be no apparent alteration. The magnesia, however, has an affinity for water; every two pounds of magnesia in becoming hydrated takes up and soldifies one pound or 27.7 cubic inches of water, and in bulk every ton of magnesia would have to find room for about 16 cubic feet of water. In finding room for this water the mortar becomes disintegrated. The action goes on whether in air or in water, but, as may be expected, more rapidly in water, and is especially disastrous in concrete work. Mr. Harrison Hayter, Vice-President of the Institution of Civil Engineers, cites instances where concrete works have failed, although built in the usual manner with cement that had stood the ordinary mechanical tests. The concrete set as hard as usual, but after a time expansion set in. In one case a vertical wall about 35 feet high was lifted about 2½ inches; in another a mass of concrete 16 feet thick had lifted from ½ to 1¼ inches. In every case a white substance of the consistency of cream was seen in the concrete. Mr. Hayter had this substance analyzed, and it was found to contain 80 per cent. of magnesian hydrate, consisting of about ⅔ magnesian oxide and about ⅓ water.

The writer made some experiments with 5 per cent. by weight of calcined magnesia added to Improved Union cement, a mixture of Union Hydraulic and Giant Portland. The magnesia was found to render the paste very plastic and easily worked. It retarded the time of setting and greatly decreased the strength of the cement. At the end of one week the pats were very soft; the outside was light gray and the interior the usual color. Briquettes made of the mixture had the following strengths:

Time Setting.	Tensile strength in lbs. per square inch.						Mixture.
	1 day.	2 days.	3 days.	5 days.	1 week	2 wks.	
20 minutes.	45	—	—	—	74	—	Neat Cement.
2 hours.	1	2	3	5	19	36	5% Calcined Magnesia added.

Good Portland cement should in no case contain more than 1 per cent. of magnesia.

Sulphuric Acid. By the rules of the École Nationale of Paris, if the sulphuric acid exceeds 1½ per cent., the cement is rejected on the chemical analysis alone. When Portland cement is properly burned it forms a very hard clinker, which is expensive to grind to the fineness now demanded by engineers, as the machinery requires constant repair. To render the grinding easier, iron slag meal is sometimes added to the cement clinker. This slag cement may be recognized by its lighter specific gravity (2.60), and by its color, which is a mauve tint in powder, while the inside of the water pat, when broken, is deep indigo. Its presence when mixed with Portland may be detected as follows: To a gill of water add about 80 drops of sulphuric acid. Into this drop 25 grains of the cement and stir rapidly with a glass rod, so as to prevent any setting, and while still stirring pour in, drop by drop, a solution of permanganate of potash (64 grains permanganate to 1 pint of water), until the red color remains permanent. Genuine Portland will require only 10 to 15 drops of the solution, whilst an adulterated cement will take considerably more (30 to 60), and a cement made from slag over 200 drops. The principle of this test is as follows: Solid permanganate of potash is at once decomposed by the addition of strong acids, but in water solution this decomposition does not at once take place except by contact with oxidizable substances. This action is apparent by the change of color, the deep purple being rendered colorless.

All Portland cements contain a small quantity of iron; thus with unadulterated cements a certain amount of the permanganate will be bleached, but cements containing iron in undue proportions will bleach a much greater quantity of the solution. A simple test for the same purpose is as follows: Place upon a clean silver coin a thin layer of cement, and drop on it a small quantity of dilute sulphuric acid (one acid to seven water), and afterwards rinse with water. If the cement be genuine Portland, the treatment will only slightly affect the color of the silver; but if slag be present in any notable proportion, a dark-brown stain will be produced.

Cement adulterated with slag and slag cement will be found finer ground and quicker setting than Portland, and it will attain its maximum strength in less time than the best Portland, but retrogression then takes place, which is most treacherous in its nature. The failure of the concrete construction of the Aberdeen Harbor Works is now attributed to the use of cement which was not true Portland, although at first it was considered that the action of the sea water was the cause; but examination of similar constructions built with good Portland cement many years previously proved that when the proper material is employed, and due care exercised in construction, permanency is assured.

Salt is often added to the water in cold weather to prevent mortar from freezing before it has set. Authorities differ regarding the effect of salt. The latest information on the subject is contained in the report of tests made at Governor's Island, New York Harbor, by Mr. John Gartland, for Col. D. C. Houston, U. S. Engineers. For salt-water tests sea water was used, and was found to increase the strength of the cement from 1 to 53 per cent., except in the case of Hoffman Rosendale, two months old. At three and six months this same cement gave higher results with sea water. About 330 briquettes from 9 brands of cement were tested, so the results seem entirely reliable. The general opinion of engineers, that sea water decreases the strength of cement, is probably based on Gillmore's experiments, which were not nearly so comprehensive as the above.

Sugar added to mortar has the same effect in preventing freezing that salt has. It increases the strength of lime mortar, especially in the centre of thick walls, but is a detriment to cement mortar. An excess of clay in cement is said by some to make the mortar more easily affected by frost, while a small excess of lime (not more than 2 per cent.) does not injure the mortar, and is much preferable to an excess of clay if exposed to the action of frost. Overclayed cements, if underburned, give a high test and set quickly, but they are liable to injury during burning by changes of temperature, while cement containing a slight excess of lime is not injured thereby.

Good Portland should be burned at a high temperature, which is indicated by high specific gravity (95 lbs. per cubic foot) and slowness in setting (2 hours or longer). The color indicates but little, since it is chiefly due to the oxides of iron and manganese. Gray or greenish-gray is considered best; bluish-gray indicates a probable excess of lime; brown an excess of clay. A mauve tint indicates adulteration with iron slag, and an undue proportion of underburned material is generally indicated by a yellowish shade, with a marked difference between the color of the hard-burned unground particles retained by a fine sieve and the finer cement which passes through the sieve. The fineness should be such that 90 per cent. by weight will pass through a sieve of 2,500 meshes per square inch made of No. 40 wire, Stubbs' wire gauge.

Made into cakes about 2½ inches square and ⅜ inch thick, and immersed in water immediately after setting, it should show no cracks at the end of a week.

The tensile strength should be about as follows, a very high breaking strength within the first four weeks generally indicating an unsound cement:

24 hours.	1 week.	1 month.	1 year.	
100	250	350	450	
to	to	to	to	
140	550	700	800	Neat cement.
—	80	100	200	
	to	to	to	
—	125	200	350	3 parts sand to 1 part cement.

The impurities should not be present in excess of the following quantities:

Magnesia	1 per cent.
Free lime	2 " "
Sulphuric acid	1½ " "
Ferric oxide	4 " "

NATURAL CEMENTS.

By natural cements are meant those which are obtained from natural stone containing lime and clay. The stone is quarried, broken into pieces, and burned in a kiln. The burnt cement is then crushed into fragments and ground between ordinary mill stones. The description of impurities in Portland cement is applicable to natural cement, except the part relating to magnesia. *Free* magnesia is as objectionable in natural cement as in Portland, but the greater portion of natural cement rocks are argillo-mag-

nesian limestones. In burning, a triple silicate of lime, alumina, and magnesia is formed, which makes a good cement, but any free magnesia will absorb water and expand as in Portland. Natural cement is generally light-colored and quick-setting, and is especially adapted to sewer work and places where the mortar is exposed to running water before setting. The requirements for good natural cement are the same as for Portland, except as regards color, weight, tensile strength, and the presence of magnesia. The tensile strength of American natural cements should be about as follows:

24 hours.	1 week.	1 month.	1 year.	
40	60	100	300	
to	to	to	to	
80	100	150	400	Neat cement.
—	30	50	200	
	to	to	to	
—	50	80	300	1 part sand to 1 part cement.

IMPROVED CEMENTS.

This name is given to natural cements mixed with Portland. The natural cements are usually light-colored and the Portland dark, so that the color of the mixture is of value in determining its quality. It is advisable to collect samples of the natural or "unimproved" cement, and also of the Portland used in the mixture. By comparing samples of the improved cement with these, a fair idea of its quality may often be obtained.

Two well-known brands are "Improved Union," manufactured by the American Cement Co., Egypt, Pa., and "Saylor's Improved Anchor." These cements have the following tensile strengths, as determined from tests of 900 briquettes from about 90 consignments made at the Division Engineer's Office, Lehigh Valley Railway (Buffalo and Geneva Branch), Batavia, N.Y.:

24 hours.	1 week.	
50 to 100	100 to 190	
av. 80	av. 130	Neat cement.
—	60 to 150	1 part sand to 1 part cement.

The strength of mortar one week old, made of equal parts of improved cement and sand, averages about two-thirds the strength of the neat cement of the same age.

The two brands of improved cements above mentioned give very high tensile tests at the end of one year when mixed with 2 parts of sand; in fact, they are nearly equal to the lower grades of Portland.

TESTING.

Space will not permit of a detailed description of the methods employed in mixing the cement and putting it into the moulds, but a few lines will be devoted to enumerating the most important mechanical tests:

(1) *Checking* or *cracking.* Make four cakes or pats of neat cement about 2½ inches square and ⅜ inch thick, with thin edges; immerse two of these as soon as they have set, and the remaining two about one hour afterwards. Also make four pats with sand (1 to 1 for natural and 1 to 3 for Portland), and immerse these in the same manner. At the end of a week examine them for cracks, and crumble them with the fingers to ascertain their strength. Sometimes cements will be found which will not bear immersion immediately after setting, and such cements should not be allowed in work under water.

(2) *Tensile strength.* Make 6 to 10 neat briquettes, one-half for 24-hour tests, and one-half for 7-day tests. The absolute strength of the cement at 24 hours is not important except on wet work, but the comparison between the 24-hour and the 7-day tests is valuable, as before explained. Also make four or more briquettes with sand (1 to 1 for natural and 3 to 1 for Portland) for 7-day tests. Some cements which will not pass the neat test will give very good results when mixed with sand; others, again, give quite opposite results, so that no idea can be formed from the neat tests as to what the action will be when mixed with sand.

In conclusion, the writer wishes to call attention to the results of tests of Canadian cements as given in Mr. F. M. Bowman's paper, published in the last Proceedings of this Society. From these figures it would appear that the average tensile strength of Canadian cements (Napanee, Thorold, and Queenston) is about 40 pounds at 7 days and 80 lbs. at 30 days.

Judging from the analysis given of Napanee cement,

Silicic acid	28.43
Alumina	10.50
Lime	43.05
Magnesia	18.02
	100.00

it would appear that a much better cement should be made. The magnesia, lime, and alumina are not in excess of the silicic acid, so that no

free lime or magnesia should be present. The writer has tested samples of cement containing over 28 per cent. magnesia, and in which the amount of silicic acid was not sufficient to form a triple silicate by about 5 per cent.; yet these samples broke at over 70 pounds at the age of 7 days. The 24-hour test, however, was nearly as high as the 7-day, showing that the cement was unsound. If engineers in Canada would specify and demand a cement giving good tests for all important works, the manufacturers would, without doubt, find a means of supplying it.

BATAVIA, N.Y., February 11th, 1891.

TECHNICAL EDUCATION.

An address delivered by Professor Galbraith at the opening of the Engineering Laboratory of the School of Practical Science, February 24, 1892 :

Mr. Chairman, Ladies, and Gentlemen,—The subject of the paper which I propose to read this evening is "Technical Education."

In selecting this subject I was influenced not only by its appropriateness to the occasion, but also by the fact, as it appears to me, that there is more or less vagueness in the public mind as to its objects and methods.

The word technical is derived from the Greek τέχνη, an art, handicraft, or trade. The idea involved in this word is the bringing forth or making of material things, as distinguished from thoughts and mental images. It is not always safe, as you know, to infer the modern meaning of a word from its derivation. Nevertheless it happens that one of the great branches of technical education, as at present understood, is exactly defined by the old Greek word, namely, the training of apprentices in the arts and handicrafts. Technical education in this sense has been in existence since the days of Tubal Cain, the instructor of every artificer in brass and iron ; and to it we owe the greater part of the material progress which has been made since the world began.

In these latter days, however, a new application has been found for the term. In consequence of the growing competition for trade among civilized nations, and the recognition of the relations of art and science to production, schools for giving artistic and scientific training to those engaged in industrial pursuits are becoming acknowledged as one of the necessities of modern times. These are known as technical art schools and technical science schools. It is to the latter alone that I propose to direct your attention this evening.

From the time of the revival of learning in the middle ages down to the present century, the energies of the universities and schools have been directed in channels having little or no connection with the material necessities of civilized beings. The sole exception has been the schools of medicine. That this should have been so may seem strange, but it appears to me that we have not far go for the explanation.

The universities and schools are not the originators of knowledge. They are simply collectors and distributors. Natural science is a thing

of modern growth. It had to reach a certain stage of development before the community could become interested in it ; and not until a demand for scientific knowledge had been created could it be admitted into schools of learning. How long, for example, is it since the physical sciences have been made a part of our Ontario school curriculum ?

Herbert Spencer, in an essay on Education, says : —"That which our school courses leave almost entirely out we thus find to be that which most nearly concerns the business of life—all our industries would cease were it not for that information which men begin to acquire as they best may after their education is said to be finished. And were it not for this information, that has been from age to age accumulated and spread by unofficial means, these industries would never have existed. Had there been no teaching but such as is given in our public schools, England would now be what it was in feudal times. That increasing acquaintance with the laws of phenomena which has through successive ages enabled us to subjugate nature to our needs, and in these days gives the common laborer comforts which, a few centuries ago, kings could not purchase, is scarcely in any degree owed to the appointed means of instructing our youth. The vital knowledge, that by which we have grown as a nation to what we are and which now underlies our whole existence, is a knowledge that has got itself taught in nooks and corners, while the ordained agencies for teaching have been mumbling little else but dead formulas."

It seems to me that these words of Spencer should be taken rather as an indictment of the community than of the schools. There has been, and may yet be to some extent, opposition on the part of men, permeated with the older culture, to the introduction of physical sciences into the schools, but this opposition is disappearing as the sciences grow and prove their fitness for a place in the educational system.

One of the main obstacles to the introduction of the teaching of science, even after its importance had been fully recognized, was the large outlay required for the necessary apparatus. Scientific investigation is both qualitative and quantitative. The teaching of science on the qualitative side consists in the enunciation and illustration of principles. The apparatus required for this purpose is comparatively inexpensive, and may be improvised to a great extent by the teacher. In many cases no apparatus at all is required—simple observation of natural phenomena being sufficient. The case is altogether different when the principles of science are to be investigated quantitatively. Instruments for making precise observations and measurements must be used. These instruments are expensive, and cannot be made by teacher or student. The highest mechanical skill is required for their manufacture, and patience, time, and opportunity for

their use. Laboratories have to be equipped, and the whole time of teacher and student given up to work with the hand, eye, and ear.

It is not to be wondered at that the introduction of science into the curriculum has been slow. Now that it has been accomplished, the question naturally arises, Wherein exists the special necessity for the establishment of technical scientific schools? I think it may be answered thus:

In all schools for the teaching of professions and callings, whether we choose to consider them technical or not, it is an admitted necessity that the teachers should be practical men in such professions and occupations. What would be thought of a medical school in which the teachers were not physicians? of a law or divinity school in which they were not lawyers and theologians? In like manner, the teachers in technical schools should be engineers, architects, manufacturers, artisans, miners, and agriculturists, if it is possible to get them. The difficulty which exists at present to a large extent, but which will disappear with the progress of technical education, is that there are very few men in the above professions and occupations who have had a sufficient training in science to make them successful teachers—their knowledge is practical, not scientific. The teacher in a technical school should be more or less acquainted with the various trades—with the methods in vogue for handling and transforming material. He should know how things are done and made in actual life and on the commercial scale. He ought to have a better perspective, so to speak, than the purely scientific man in reference to the needs of his students, and should be able to meet them more nearly on their own plane, and interest them in science by selecting his illustrations from their work, actual or prospective. It is of the first importance that he should keep himself informed in the latest manufacturing processes. This cannot be done by reading. The text-books are always years behind the times in this respect. Manufacturing and engineering periodicals are better, but still they convey little or no idea of the scale on which work is done. Personal observation, travel, and engaging in outside work whenever possible are the only methods whereby the teachers in technical schools can gather the proper material for illustrating scientific principles and maintaining the interest of students in their work.

The principal work of a technical school is the teaching of science, and not, as many suppose, to turn out fully fledged engineers, architects, manufacturers, and tradesmen; all that it can pretend to do is to turn out partially educated men. The graduates must supplement the work in the school by practical experience in after life before they acquire the right to call themselves practical men.

The practical work of the school differs in many respects from the practical work of actual life. Where it is work of the same kind, as, for instance, drawing, designing, the use of surveying instruments, lathework, smithwork, etc, yet the feeling of reality and responsibility is lacking. It is a very different thing to make mistakes in school work from making mistakes in similar work in actual life. A man is vastly more impressed by the necessary punishment which follows mistakes in the serious business of life than he can be by the arbitrary penalties instituted by the faculty.

Again, there is a great body of knowledge necessary to complete a man's practical education which it would be only an utter loss of time to attempt to give in a school, simply because there are no well-defined threads of scientific thought upon which to string it. Three-quarters of the information to be found in an engineer's handbook would be useless in the curriculum, although all-important in practice. Such knowledge becomes useful only when impressed by experience.

The establishment of engineering laboratories marks a new departure in technical education. Surely it will be said that the work in these laboratories is practical. So it is, but not perhaps in the sense in which the question is put. The steam engine in an engineering laboratory is not used for the same purpose as the factory engine. In the shop it is used for manufacturing purposes; it is placed in the laboratory for the purpose of being experimented upon. In the laboratory it is tried at different speeds, worked condensing and non-condensing, with varying steam pressures, with and without steam-jacketing, with different amounts of lead and cushioning, with different counterbalances for crank and connecting-rod, with varying clearances, with simple and multiple expansion. The work done at the main shaft is accurately measured; likewise the work in the cylinder—the feed water and condensing water are weighed—the degree of dryness of the steam determined. In short, in the laboratory all the conditions which may affect actual practice are experimentally investigated. It is only in this way that the principles governing the construction and action of engines can be fully determined.

What would an employer do with a man who should attempt any such work with the factory engine? He would simply give him to understand that his usefulness was gone, and that he had better look for employment at the School of Practical Science.

Again, since the teaching of principles is the main object of a school of applied science, it seldom happens to be useful to complete any of what is ordinarily called practical work, as would be necessary in actual life. To do so would occupy too much time. Practical constructions involve so many and various considerations and methods that the attempt to

complete them would simply be reverting to the old state of affairs, when the apprentice gained his knowledge altogether on actual work. The study of the sciences would be so much interrupted and confused by such a method as to be of very little value. The practical work of a technical school, in so far as it is of the same kind as that of after life, must be selected and pursued rather as illustrating the principles of the special science under consideration than for the sake of the work itself.

In practical life, on the other hand, the result is the thing aimed at, and it matters nothing to those who pay for this result how it was arrived at, whether by rule of thumb or by the application of scientific principles. The work of the school is more analytic than synthetic, more destructive than constructive. The student pulls, as it were, machines to pieces in order that in after life he may learn to put them together. His proper work is investigation and experiment. After he graduates, his work, on the contrary, is construction and design. It would not be advisable to give equal prominence to both kinds of work in the school. The time is too short, and the feeling of responsibility which should govern construction and design is absent and cannot be artificially excited. Make-believe work is essentially false and unscientific.

The arrangement of the courses of study in the School of Practical Science is in accordance with these principles. The departments of instruction are civil, mining, sanitary, mechanical, and electrical engineering —architecture, analytical and applied chemistry, and mineralogy and geology.

In addition to the instruction given in the school, the students take such work in the University of Toronto as is necessary. The University work is mathematics, physics, and chemistry. Up to the present session mineralogy and geology have also been taken in the University. The greater part of this work will henceforth be taken in the school.

Through the exertions of the Hon. the Minister of Education and the liberality of the Provincial Legislature, an engineering laboratory has been established, and is now approaching completion. The Dominion Government have also contributed their quota by relieving the school from the payment of customs duties on such apparatus and machinery as it was found necessary to import from abroad.

It may be of interest to you to have a short description of the main features of this laboratory.

It consists of three departments: First, the department for testing materials of construction. Second, the department for investigating the principles governing the applications of power. This department is subdivided into the steam laboratory, the hydraulic laboratory, and the electrical laboratory.

The third department may be termed a geodetic and astronomical laboratory, as the work to be done in it, which relates principally to standards of length and time, is of special importance in these sciences.

In order to prepare specimens for the testing machines, a shop has been fitted up with a number of high-class machine tools specially suited for reducing the specimens to the requisite shapes and dimensions with a minimum of hard labor. It is also fitted with the necessary appliances for making ordinary repairs.

The machines in the department for testing materials are the following:

An Emery 50-ton machine built by Wm. Sellers & Co., of Philadelphia, for making tests in tension and compression.

A Riehle 100-ton machine for making tests in tension, compression, shearing, and cross-breaking. It will take in posts twelve feet long and beams up to eighteen feet in length.

An Olsen torsion machine for testing the strength and elasticity of shafting. This machine will twist shafts up to sixteen feet in length and two inches in diameter.

The last machine in this department is a Riehle 2,000 lbs. cement testing machine. The cement testing laboratory is fitted with the usual accessories.

These machines are all of the latest and most improved designs, and, with the exception of the cement machine, there are at present no duplicates of them in existence.

In the power department there are under the division steam two boilers, a Babcock & Wilcox 52 horse-power and a Harrison-Wharton 12 horse-power boiler. The engine is a 50 horse-power Brown automatic cut-off engine, built by the Polson Iron Works Co., Toronto, specially for experimental purposes. It is steam-jacketed and has three alternative exhausts, to the open air, to a jet condenser, and to a Wheeler surface condenser, kindly presented to the school by Mr. F. M. Wheeler, of New York, the inventor. There are also a Blake circulating pump, a Knowles air pump, and a Blake feed pump, the latter of which was a gift from the manufacturers. The engine is arranged so that it may be compounded when there are funds for the purpose. To have built the engine compound in the first place was deemed inadvisable, as the money was urgently needed for other work.

A machine now being constructed by the Riehle Bros., of Philadelphia, for measuring journal friction and testing lubricants, will shortly be placed in position. It is fitted with an ordinary railway car journal and box. The maximum loads occurring in practice can be applied. The maximum speed will be 50 miles an hour. This machine is expected to be an im-

provement upon any yet built for a similar purpose. I received a letter a few days ago from a railway in the Western States which intends to order one if we give a satisfactory report.

The hydraulic division of the laboratory is furnished with a three throw pump with double acting cylinders, built specially for the school by Northey & Co., of Toronto. It has adjustable strokes, and has a maximum capacity of half a million gallons per day. It has been designed to produce an extremely steady pressure, this being requisite for hydraulic experiments. The maximum head under which it works is 230 feet. There will be practically no addition to the running expenses of the laboratory due to the working of this pump, as the same water will be used over and over again, and the power will be furnished by the experimental engine. In order to make engine experiments the coal has to be burned in any case, and the necessary resistance supplied either by a brake or otherwise. Driving the pump is one method of doing this. A three feet turbine wheel of the jet type, built by the Fensom Elevator Co., of Toronto, forms a part of the same equipment. The pump furnishes the power for this wheel. There are two large tanks, built by the Doty Engine Co., of Toronto, for experiments on the discharge of water through orifices and over weirs.

The above apparatus is arranged with a view to testing water meters, measuring the discharge of fire streams and various other hydraulic investigations within the capacity of the plant.

The electrical division of the laboratory is equipped with the following dynamos :

Edison, Ball, Thomson-Houston, two Gülcher machines and a Westinghouse alternator with transformers, a Crocker-Wheeler, and a Kay motor, also two small fan motors.

There are in connection with it a Roberts storage battery, a gravity primary battary, and a fair equipment of lamps, arc and incandescent, of different types.

The power department is equipped with the usual measuring instruments, indicators, gauges, gauge-testing apparatus, scales, brakes, dynamometers, ammeters, voltmeters, resistances, galvanometers, etc.

In the geodetic and astronomical department are 100 feet and 66 feet standard of length, a 10 feet Rogers comparator with graduating attachment, a Howard astronomical clock and electro-chronograph, a Troughton & Simms 10-inch theodolite, and all the ordinary surveying instruments.

That you may not leave this building to-night under the mistaken impression that our equipment is complete, and that we can spend no more money, I propose to conclude this paper by touching upon some of our most pressing wants.

The department of architecture has recently been established, and is provided with a good collection of photographs and drawings. A large number of casts, models, and plates will be required, however, to complete the equipment.

The oldest laboratory in the school is that in the department of analytical and applied chemistry. It it well equipped for general work in qualitative and quantitative analysis; also for the quantitative analysis of food, air, water, fuels, and illuminating gas. Special apparatus is now urgently needed for the analysis of iron, steel, and other materials of construction, to supplement the testing work of the engineering laboratory.

The important department of mineralogy, assaying, and mining has at present a very meagre laboratory equipment. In view of the interest which is now being taken in Canadian mining, it is to be hoped that this state of affairs will be immediately improved, and that the School of Practical Science may be enabled during the next session to offer to those who may desire it a complete course of instruction in mining engineering and metallurgy.

In sanitary engineering we have at present no special laboratory. Our hydraulic plant can be utilized largely in connection with this department, but in addition a collection of models is very necessary for purposes of illustration.

As cities increase and population grows denser, sanitary problems become more complicated, and have to be dealt with by communities and governments instead of depending on individual action. As a consequence, sanitary engineering is becoming a most important branch of the profession, and a prominent position should be assigned to it in the curriculum of a technical school.

The rapid development of electrical lighting is bringing into prominence the question of the measurement of the illuminating power of electric lights. Special difficulties surround this problem, and it is desirable that our electrical laboratory should be furnished with the means for making such investigations.

It would greatly facilitate the work of the school in all departments to have means for making photographic lantern slides. Ordinary charts and maps soon grow out of date, and take up a large amount of room. A photographic outfit would give the means of making lantern slides of all the latest illustrations of machinery and construction that are published in engineering, manufacturing, and architectural journals, and of exhibiting them to large classes.

Another pressing want is a good technical library. If it were not for our periodicals, we should have no library at all; and while the Toronto

Public Library has a good collection of works on technical subjects, yet they are, for all practical purposes, beyond the reach of our students.

Collections of rocks, minerals, and products illustrating various stages of manufacturing are very much needed in the departments of mining and applied chemistry.

In view of these pressing demands the question will naturally arise, What is to be the outcome of this technical education—where are the young men to find employment? If the country cannot support them, what justification can there be for the expenditure? It seems to me that this is a question in political economy, and might properly be referred to the distinguished head of that department in the University of Toronto or to our friends the Trades and Labor Council.

My answer can only be vague and general. I would reply by asking why we have gone into debt for the purpose of building canals and railways, docks and harbors—why have we built expensive houses of parliament, churches and jails, sewers and water works, colleges and poor-houses? Is it not because we feel that we are as good as our brothers across the sea or as our cousins south of the lakes—are we not a civilized people, and have we not a right to these luxuries whether we can pay for them or not? Is it not as useful to the country to turn out men educated as engineers, architects, mechanics, miners, and farmers as to turn out lawyers, doctors, ministers, and bankers? Will not the graduates of our technical schools have that very education which our mechanics, artisans, and tradesmen of all classes most desire, and of the necessity for which they are reminded every hour? If you had seen with me the crowd of eager men, young and old, who assembled the other evening at the opening of the Toronto Technical School, you would no longer have any doubt as to the desirability and necessity of technical education. If the country cannot support such men, so much the worse for the country, and so much the better for that country in which they find employment.

If we are ever to pay off our foreign debt and trade on equal terms with other nations, we must develop our material resources with economy and skill, and among the means making towards this end not the least promising is Technical Education.

EXTRACTS FROM LETTERS READ BEFORE THE SOCIETY.

BRIDGEWORK.

By Mr. F. M. Bowman,

Bridge Department, Pennsylvania Steel Co., Steelton, Pa., December 31st, 1891.

Mr. President and Gentlemen,—It may not be amiss to give you a few ideas that have occurred to me during my connection with bridgework. The greatest difficulty to the young graduate intending to take up this branch of engineering is to get a start. This, of course, is a difficulty in all branches, but it seems to be peculiarly present in the case of bridgework. In other branches the trouble generally lies in the supply being greater than the demand, and very often experienced men are as unable to secure employment as the less experienced. But it is different with bridgework. Almost every issue of the *Engineering News* contains advertisements for experienced bridge designers and draughtsmen, while the contra advertisements of such men seeking employment are not so numerous.

Having made it clear, then, that securing initial employment is the one great obstacle of the beginner, I shall now state some methods which have been adopted to overcome this difficulty. The method which meets with least success is that of applying by letter. Such a letter may or may not be answered, but in either case it is filed away, and in the case of the uninitiated (the one under consideration) it is never referred to again. If, through some friend or otherwise, an engagement can be made at a nominal salary, it is wise to make it, trusting to ability to secure a speedy advancement. In other cases, again, men are often successful by applying personally. This is probably the best way of ensuring success. Again, I have known several young graduates of the best American engineering schools to secure the work of blue-printer or some like position, and with the opportunities thus afforded were soon advanced. Some companies, such as G. W. G. Ferris & Co., of Pittsburg, Pa., make special arrangements with young graduates to give a fixed salary to those who contract to stay with them for two years or so; the company, on their part, agreeing not only to expound the mysteries of the bridge, but also to assist in securing for their employee a good position after the two years have expired.

It is necessary to work for at least two years as a bridge draughtsman

in order to become thoroughly familiar with all details and connections, so that one may know how to arrange, to the best advantage, the details of his design. The work of these years is, of course, very hard and tedious, and one becomes eager to get into the higher positions of designing, estimating, inspecting, and testing. During this interval, however, he becomes a good draughtsman, and at the same time has no inconsiderable experience in the other lines.

In view of the fact that each engineer has his own methods and each company its own apparatus and equipments, I think it is advisable for the younger engineer to change employers at intervals in order to have the advantage of the methods and equipage of each. This may be slightly detrimental from a financial point of view at first, but the first cost is made up for in the end.

CIVIL ENGINEERING (INCLUDING MINING ENGINEERING).

By H. E. T. Haultain.

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All the subjects included in the departments of "Civil Engineering (including Mining Engineering)" and "Mechanical and Electrical Engineering" *ought* to be studied by the mining engineer, and much of the departments of "Architecture" and "Analytical" and applied "Chemistry," and of course all of "Assaying and Mining Geology," besides the subjects ore-winning and ore-treating, the latter of which is an especially large and heavy subject.

Let us consider what is expected of the mining engineer, considering the term "mining engineer" to mean the man employed for the designing of the whole plant, and not the one individual man in charge.

Let us commence at the end, when all the work has been done. Consider a fairly large mine in one of the new countries, where a few years ago it was all a wilderness. What have we? A mine containing several miles of shafts, adits, winzes, galleries, rises, drives, etc., etc., out of which is being blasted and raised to the surface 500 or more tons of rock-matter daily. This 500 tons of rock-matter has to be brought into the condition

of fine sand, and has to pass through various and complicated processes to free the pure mineral or minerals from each other, and from waste products, and then, in all probability, the separated mineral has to go through several chemical processes, equally varied and complicated, to obtain the metal or metals before it leaves the mine.

Underground are required air compressors and drills, ventilators, miles of tramways worked by animal power perhaps, (but very soon to be worked by electricity,) hoisting machinery, both for raising this 500 tons and also for lowering and raising several hundred men to and from a depth of 500 to 1000 feet or more.*

Pumps also will certainly be required, perhaps to pump 1000 gallons a minute to a height of 500 feet. All this will require 300 horse power or more, which must be supplied by steam or water power in connection with electricity. On the surface a small system of railways will be required to carry the different products to the different places. The ore has to be crushed and then stamped, and then put through the various washing processes to free it from the waste stuff, all of which means a great deal of machinery, requiring at least 500 horse power. Then come the smelting processes, which form a department of themselves, but which come under the head of the general term "Mining Engineering." Thus we require at least 800 horse power, and this must be supplied by steam or water power. If there is no coal mine near, or if wood is not over-plentiful or cheap, then if water power can be had within 20 miles, it would be best to use the water power and electricity. This entails a good deal of hydraulic work, dams, canals, sluices, etc. To keep all this in order are required machine shops, carpenter shops, smithies, and a sawmill, etc., and to work the whole affair there may be 1000 men or more, with, say, 2000 depending on them, and all these have to be housed; this, and much more, comes into the work of the mining engineer.

The mining engineer has had to know all about the geology of the place before sinking his shafts and driving his adits. He has to erect houses for his work and his men, and shops and mills to supply his materials. If electricity is not used, steam engines of all kinds will be required for hauling, hoisting, pumping, air compressing, locomotives, and for driving general machinery; he has to erect these, and, in all probability, to teach his men how to use and look after them; he has an air-compression system to devise, and erect besides systems of haulage and of ventilation. On the surface, all his buildings to design and erect, and a system of tram-lines to design, overhead or otherwise, and his crushing and stamping

*The deepest mines in the world are in Pzribrain in Bohemia.

mills, his sieves and separators, and pigs and puddles, and shaking-tables, and concentrators of all kinds and descriptions. If it is gold he is after, he requires amalgamators and chlorination plant, etc., etc., *ad libitum*. Then there are the smelting furnaces and all that belongs to that department in the shape of furnaces, both reverberatory and blast, for roasting, smelting, and refining. Then all the shops, smithies, and storehouses, and the whole place has to be lighted. There is a young town to build, and drainage to look after, besides roads, bridges, dams, canals, and sluices for his water power. If he is going to have electricity, the mining engineer has to design and erect his electric plant, and teach his men how to look after it, and, above all, he has to manage 1000 men or more on the minimum of wages, by no means an easy thing in these days of agitators and strikes; while above and beyond all, he has his directors in London to humor and satisfy.

This is a rough outline of part of the work of the mining engineer. He may also be expected to undertake geological surveys, or to report on new mining districts, which means geology, mineralogy, paleontology, etc., in no small measure. Then there are mining engineers for coal, which is a branch entirely separate from metalliferous mining, and yet "Civil Engineering (including Mining Engineering)."

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Young students in the commencement of their studies, as they see in the outside world more and more of what is expected of the engineer in actual work, when they see bridges, and railways, and machinery being constructed, and consider that they will be called upon to do the same sort of thing, begin to ask when and where they are going to learn how to do this; this, which, being the most prominent result of engineering work, fills up their idea of engineering. They are anxious to be doing this kind of thing, and are apt to get uneasy at so much time being spent upon Algebra, and Euclid, and Conic sections, and such like mathematical speculations, especially when they see the "practical" side of the question handed over to the uncertainties of "vacation notes." And so does one, on first looking at it, wonder how Civil Engineering, in contradistinction to mechanical and other engineering, is going to include Mining Engineering, and, still more, how any building within four walls can pretend to teach engineering, be it civil, or mechanical, or mining—to teach men in three short years of seven months each to cope with all the various forms and conditions of nature in ways and means suitable to the conditions and requirements of modern circumstances. But does any institution in the world pretend to teach engineering "practice" in its entirety? No; it cannot.

Facts and formulæ, methods of nature and methods of reasoning, are

taught; but methods of practice are left almost entirely to be learned in actual work. With the main exceptions of surveying and draughting, in which the school has a very thorough course in both theory and practice, there is very little of actual office or field work attempted. This is only as it must be.

Before we learn methods of practice, we ought to learn methods of reasoning; if we have our methods of reasoning, the methods of practice follow easily and quickly.

We can divide the engineer's field of study into three divisions: (1) Methods of nature, including facts which may hardly be said to be methods, *e.g.*, the three angles of a triangle are equal to two right angles. Under this heading I would include all the laws of Chemistry, Optics, Hydrostatics, Dynamics, and Mechanics, etc., and nature's methods as shown in Mineralogy, Geology, etc., and also the facts of geometry, and those facts connected with the peculiarities of substances—such as, iron can sustain a tension of so many pounds to the inch.

(2) Methods of reasoning, both in connection with the methods of nature, as in the theory of internal stress; also methods of reasoning, pure and simple, which in themselves are of no ultimate value beyond mental training, but which form foundations and steps for further reasoning, as in algebra.

(3) Methods of practical dealing with the methods of nature, methods of practice in turning the methods of nature to our use, *e.g.*, turning the energy of the combustion of coal into a form convenient for use, as in the steam engine or gas engine; the application in the construction of a bridge of the power of iron to resist stress, and of the facts of geometry, and the theory of mechanics, together with a consideration of all the circumstances surrounding both the present construction and the future life of the bridge.

The school training of an engineering student consists chiefly in Nos. 1 and 2, and in preparing him to pursue his studies in No. 3.

We have the difference between the so-called "theoretical man" and "practical man." The man who is only practical and sneers at the theoretical man is only in No. 3, and knows very little of Nos. 1 and 2. But it is self-evident how extremely more practical the theoretically trained man can be when he has his methods of practice.

The engineering student's chief work should be in the training of his mind; the training of the mind in methods of reasoning, thought, and observation. Consequently do not fret because you will not be able to build a "Forth" bridge on graduating, but devote yourself to this training of your minds.

The main thing, I believe, consists in the training of the mind; quick-

ness, clearness, and accuracy are what must be aimed at. The mind can be trained to quickness and clearness in reasoning most successfully in abstract reasonings, pure and simple; so algebra and Euclid serve two purposes: not only are they methods of reasoning and the foundation for further methods, but they form a splendid gymnasium for the training of the mind.

There are two functions of the brain which are most valuable, and which the course at the school, together with the Engineering Society, particularly help—I mean reading and observation. It is by means of these two that the student is going to advance himself in the division No. 3. It is in the observing of actual work, and in the reading about work done, that the student has the means of learning methods of practice. The student, after graduating, requires to be employed on actual work.

Consequently these subjects require careful and studious attention, as they will be the immediate means of further advance. Having got employment, read and observe, and assimilate what you read and observe. You know the word assimilate? When a substance is assimilated, it is not only digested, but becomes an intimate part of the animal assimilating it. Don't imagine, by any means, that your course is finished on graduating. Not at all; you have still *everything* to learn; but you are in a position to learn it. You have been taught nature's methods; you have been taught to think, to observe, and to read. You have been taught enough of methods of practice to make yourself thoroughly useful to your employer, and your duty is to learn methods of practice, methods of dealing with nature as found most suitable to modern circumstances.

A word, before closing, about mining methods. In speaking of the work done by the mining engineer, I did by no means mean that all the work described would have to be done by one man; that would be a practical impossibility. In actual work, the greater part of the designing of the appliances would, in all probability, be done by Frazer and Chalmers, of Chicago, New York, Denver, Lima, Tokio, Johannesburg, London, and other places, the chief makers of mining machinery.

The mining engineer in charge of the work would find out what he wanted and give the outline of the general design to this or some other manufacturing company, and would leave all details to them, unless he were a specialist in some particular branch.

The designing of the appliances belongs to the general department of Mining Engineering, and consequently I used the term mining engineer to represent the person or persons employed on the designing of the whole plant. If there were much electricity in connection with the mine, there ought to be a specialist, a mining electrician, as also a specialist for the smelting and assaying, and the same in other departments.

We find that in considering the general subject of Mining Engineering under the three heads mentioned, that under No. 1 there are some special methods of nature to be studied—mineralogy, geology, and kindred subjects, in addition to the subjects studied for Civil Engineering only; that under No. 2 the methods of reasoning are the same both for Mining and Civil Engineering. Thus we see that the course in Civil Engineering, when it includes Mineralogy, Geology, assaying, and some ore-dressing, can quite consistently include Mining Engineering; though, perhaps, it would be better if the mining student *could get a little more mechanical work than is generally included in the ordinary Civil Engineering course.*

I believe *every* engineer should have a *fair knowledge of electricity.*

London, England, August, 1891.

NOTES AND COMMENTS.

This session has witnessed a number of renovations and changes in the working of the Society.

Among some of its undertakings may be cited the supplying of two or three grades of egg-shell drafting paper, cut to standard size. This is a great saving of inconvenience, labor, and expense to the students who, although not members of the Society, have the privilege of obtaining this paper at practically cost price. This alone should induce *all* students to become members; for, leaving out of consideration the great benefits derived from attendance at meetings and the discussion of practical questions closely connected with their work, the matter of expense alone leaves no doubt as to the relative costs of each side.

Another innovation, of perhaps minor importance, was the selection and purchasing of school colors by the Society. Although not exactly pertaining to the aims and objects of our body, yet being the principal organization of the school, and matters of this nature being better done by an organization than by any other means, it was taken in hand, and has been very satisfactorily performed. The colors are at once unique and distinct, and characteristic of the school shield, which bears the colors, blue, gold, and white.

The establishment of the Fourth year, which was looked forward to with great interest by the students, is now a thing of reality.

While at present no degree is connected with it, it has been practically promised and therefore virtually secured. The diploma already given with graduation must not be belittled; but it is conceded that a degree bears more weight and is of greater value. The degree in question is not one which may be tacked on indiscriminately by almost any one with a little engineering practice, as the letters C. E. often are, and therefore in that respect is perhaps of higher grade.

The work of the Fourth year student consists chiefly in testing and experimenting with the material, machines, and instruments placed in the Laboratory for his use. This Laboratory is well equipped with all the necessary machinery, etc., requisite for thorough tests and experiments in almost every branch of engineering.

An exchange in pamphlets with the Engineering Society of Ann Arbor University, Michigan, was made in the early part of this session. Their

annual is entitled the "Technic," containing matter well and clearly written. Having about 100 pages of varied subjects, it serves the purpose of a very instructive text book, and also as a book of reference. Electricity, Architectural Engineering, and Mathematics of Least Squares, all receive a thorough and intelligent consideration; nothing of practical importance being untouched.

We are also indebted to the Provincial Land Surveyors for their exchange: "The Proceedings of the Provincial Land Surveyors of Ontario." It is a publication containing much useful information to the intending P. L. S., giving at once clear and concise descriptions of operations and works connected with surveying, which prove of great assistance to the comparatively inexperienced practiser, and serve as a reliable source of information upon which to base similar operations or structures.

In the "Extracts from Mr. H. E. T. Haultain's Letter," a somewhat detailed description of the duties of the Mining Engineer is given. It conveys the impression that mining engineering should be a distinct and complete course of itself, and although at present we have it combined or included in civil engineering, yet the practical work in both is to a great extent of distinctive character. It would also appear from his description that the civil, mechanical, and electrical were included or were, at least, very requisite in the location, management, and operation of a mine and its varied machinery, etc.

In two or three of our previous numbers we are indebted to Mr. Haultain for some very excellent and practical papers and letters on his own work. Much interest is excited and much instruction derived from communications of this nature. It is to be hoped that many of the other graduates, who have not yet done so, may favor us with something similar; for the experience of those graduating from the school proves interesting to a greater extent than papers wholly prepared from compilation or reading. To those who hope to follow in footsteps of the graduates, nothing of the outside practice is more closely connected with them and their work than the experience of those who have so closely preceded them.

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